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Health Effects of Aerosols Emitted from an Activated Sludge Plant

Illinois Univ at the Medical Center, Chicago

Prepared for

Health Effects Research Lab, Cincinnati, OH

May 79

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Health Effects of Aerosols Emitted from an Activated Sludge Plant

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That infectious agents are emitted into the atmosphere during the aeration phase of sewage treatment is well established in the literature, but it is not well documented that the emissions of particles containing bacteria and viruses are hazardous to the health of persons residing near the plant site. This study was designed to determine whether or not the health of persons exposed to aerosols emitted by a sewage treatment plant is significantly different from persons living in lesser exposed areas around the plant site.

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HEALTH EFFECTS OF AEROSOLS EMITTED FROM AN ACTIVATED SLUDGE PLANT

by

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DISCLAIMER

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our national environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The primary mission of the Health Effects Research Laboratory in Cincinnati (HERL) is to provide a sound health effects data base in support of the regulatory activities of the EPA. To this end, HERL conducts a research program to identify, characterize, and quantitate harmful effects of pollutants that may result from exposure to chemical, physical, or biological agents found in the environment. In addition to the valuable health information generated by these activities, new research techniques and methods are being developed that contribute to a better understanding of human biochemical and physiological functions, and how these functions are altered by low-level insults.

This report provides an assessment and discussion of data obtained in a community having an activated sludge wastewater treatment plant, to determine if the plant could be related to any illness in the community. With a better understanding of the health effects, measures can be developed to reduce exposure to potentially harmful materials.

RJ Garner.

R.J. Garner
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ABSTRACT

Activated sludge processes have the potential for discharging aerosols containing pathogenic organisms into the ambient air which can be disseminated by winds over adjacent residential areas. An 8-month environmental health study was carried out in a 1.6-km area surrounding an activated sludge plant which processes $1.1x10^9$ liters (292 MGD) sewage per day. A cross-sectional demographic and health survey of a random sample of persons residing within the study area revealed that they were relatively homogeneous, predominately white, upper middle class, with no remarkable prevalence of health problems. Seven hundred and twenty four people (246 families) volunteered to record self-reported illnesses at biweekly intervals. Throat and stool specimens were collected from a selected subsample of about 161 persons providing a total of 1,298 specimens analyzed for pathogenic bacteria and viruses. In addition, 318 persons submitted paired blood samples at the beginning and at the end of the study period to determine prevalence and incidence of infections to five coxsackievirus and four Echovirus types.

In order to characterize the study area environmental air quality, measurements of total viable particles (total aerobic bacteria-containing particles), total coliform bacteria, total suspended particulates (TSP), ammonia (NH_3), hydrogen sulfide (H_2S), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), chlorine (Cl_2), particulate sulfates ($SO_4^=$), nitrates (NO_3^-), vanadium (V), chromium (Cr), manganese (Mn), nickel (Ni), copper (Cu), arsenic (As), selenium (Se), cadmium (Cd), tin (Sn), antimony (Sb), mercury (Hg), and lead (Pb) were made at regular intervals at different distances from the plant in ambient air. Grab samples of sewage were collected concurrently with the air measurements and were analyzed for total viable particles, total coliform bacteria, trace metals, $SO_4^=$, and NO_3^-. A limited number of measurements were also made of viruses and coliphage in sewage and air.

The environmental measurements were used to develop study period (8-month) exposure indices for each household for total viable particles, TSP, NO_2, SO_2, NO_3^-, $SO_4^=$, V, Mn, Cu, and Pb; a similar 2.5-month exposure index was developed for total coliform bacteria. Not enough data were available for other pollution parameters to justify development of additional exposure indices. Results of the health survey and the specimen and serological analyses were compared with the household exposure indices.

No remarkable correlations were found between the exposure indices and the rate of self-reported illnesses or of bacterial or viral infection rates determined by laboratory analysis. However, the plant was identified as a source of total viable particles and total coliform bacteria. The 0.8-km (½-mile) downwind study-period average total viable particle concentration

(198 particles/m^3) was statistically higher ($p < 0.05$) than the 0.8-km (½-mile) upwind average (141 particles/m^3). The plant average (376 particles m^3) was also significantly higher ($p < 0.05$) than the 0.8-km upwind average. The 1.6-km (1-mile) downwind average (155 particles/m^3), when corrected for another source of viable particles in the study area, was also higher than the upwind value but the difference was without statistical significance. The total coliform bacteria 2.5-month average also showed similar statistical differences ($p < 0.05$) between the plant (6.87 coliforms/m^3) and the 0.8-km upwind concentrations (1.15 coliforms/m^3). Only the plant was significantly greater ($p < 0.05$) than the upwind average. Environmental levels of the other pollution parameters could not be associated with plant emissions or plant operating characteristics.

The overall conclusion that this activated sludge sewage treatment plant had no obvious adverse health effects on residents potentially exposed to aerosol emissions must be tempered by the recognition that only a very small number of people were exposed to the highest pollution levels. It is also important to note that this plant was not a source of high concentrations of viable particles, gases, or metals to the study area.

This report was submitted in fulfillment of Grant No. R-805003 by the School of Public Health, University of Illinois at the Medical Center under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1, 1976 to December 31, 1977, and work was completed as of April 30, 1979.

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Dr. Cecil Lue-Hing, Director of Research, Gary Ziols, and William Eyre of the Metropolitan Sanitary District of Greater Chicago are gratefully acknowledged for their assistance in supplying plant data and cooperation and support in allowing us to enter the North Side Sewage Treatment Works in Skokie, Illinois to collect air and sewage samples and meteorological data during the course of this study.

The preparation of the survey instruments and the tabulation of the survey data were conducted by the Survey Research Laboratory, University of Illinois Circle Campus, under the direction of Dr. R. Warnecke to whom we are greatly indebted. In particular, we wish to thank Ms. B. Eastman, coordinator of the questionnaire survey, for her dedication to the task.

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SECTION 1

INTRODUCTION

OBJECTIVES OF STUDY

That infectious agents are emitted into the atmosphere during the aeration phase of sewage treatment is well established in the literature, but it is not well documented that the emissions of particles containing bacteria and viruses are hazardous to the health of persons residing near the plant site. This study was designed to determine whether or not the health of persons exposed to aerosols emitted by a sewage treatment plant is significantly different from persons living in lesser exposed areas around the plant site. Field and laboratory studies to evaluate the environmental and health status included:

1) assessment of microorganisms and metal and gaseous constituents in sewage with emphasis on those components considered to be hazardous to man's health;
2) assessment of the quality, quantity, and distribution of viable particles, non-viable particles, and gases in the air originating from the sewage treatment plant and in the community;
3) assessment of the health, particularly with reference to infectious diseases, of persons living in areas exposed to different concentrations of viable and non-viable pollutants originating from the plant. The health assessment was determined from: a) a health questionnaire survey, b) a health watch, and c) microbiological and serological analysis of throat, stool, and blood specimens obtained from volunteer participants;
4) interrelating the respective data obtained regarding sewage constituents, aerosol content, and meteorological conditions affecting aerosol survival and dispersion, with retrospective and prospective health information and microbiological and serological laboratory studies of the study population in order to determine the potential and actual health hazard of exposure to sewage aerosols.

STUDY DESIGN

The sewage treatment plant, referred to as the North Side Sewage Treatment Works, used in this study is located in Skokie, Illinois. An area within a 1.6-kilometer radius of the treatment plant was designated as the study area, which was estimated to consist of approximately 16,000 persons.

In an attempt to determine whether or not the sewage treatment plant was hazardous to the health of the community exposed to the plant aerosols, several measurements of health were made.

First, a retrospective questionnaire survey of the types of diseases, particularly of infectious character, occurring in the previous 12 months was conducted.

Second, a health watch which was a prospective study of self-reported diseases by the sample population as well as microbiological studies of throat and fecal specimen cultures, was conducted. Biweekly diaries of self-reported infectious diseases and biweekly throat and/or fecal specimens of members of selected households were collected by field staff. Also, two blood samples were collected from this study group, one at the onset of the study and the second 8 months later. The serosurvey provided both prevalence data of certain types of infectious diseases encountered in the past and incidence of those encountered during the study period.

The analysis and interpretation of the health information collected was based on the biometric and epidemiological concept of a dose-response relationship; i.e., persons living in areas more highly exposed to aerosols originating at the plant site may have different frequencies or types of health problems than persons living in low exposure areas. Accordingly, a separate control population group was not needed. Conceptually, if the sewage treatment plant was the source of infections, trace metals and gases, or other hazardous materials, then the level of exposure may be directly related to the number of infections and/or diseases occurring in the exposed population.

A sewage and air monitoring program was conducted to characterize the type and extent of exposure of populations living within the study area to pollutants emitted by the plant. The air pollutants monitored included three general categories; viable particles, non-viable particles, and gases. In addition, these substances were monitored in the sewage at different stages of treatment.

The environmental measurement program characterized through 8 months of monitoring the exposure of individuals living in the vicinity of the plant. This was accomplished by generating models of air concentrations within the study area for each pollutant measured. These concentrations were used to develop a personal exposure index for each participant, and these exposure indices were the basis for comparative health analysis. In addition, through use of these measurements, an attempt was made to relate the dispersion of pollutants to appropriate meteorological parameters and a plant operation data model. This model would attempt to predict air concentrations of each pollutant at various distances from the plant based on such factors as wastewater aeration rate, wind speed and direction, concentration of pollutant in wastewater, and solar radiation.

All health data obtained from the questionnaire and the Health Watch and the corresponding laboratory results were recorded into a personal health file for each interviewee and/or participant in the study. These personal health files were referenced according to an individual and household identification number. Incidence rates for various illness categories were obtained for each person and/or household. A pollution exposure index was available for each person or household. From these data sets a dose-response relationship between different levels of exposure to sewage plant emissions and illness and infection rates was investigated.

Standard techniques such as regression and analysis of variance were used to relate the health and environmental data.

BACKGROUND AND LITERATURE REVIEW

Viable Particles

Emphasis in past studies has been primarily placed on the dispersion of aerosols containing microorganisms. The organisms either were considered to be disease-producing in themselves or indicators of disease-producing organisms (1-8).

The implication that viable aerosols could be a threat to the health of man working or living in the exposed area is of public health concern. There have been few definitive studies, however, to strengthen or to substantiate that implication. This is probably true not from lack of concern of the potential health risk to man, but because of a recognition of the complexity of factors affecting the viability of microorganisms in aerosols. The agents emitted from wastewaters may be members of genera and species known to be pathogenic for man but whether these organisms survive in the aerosol environment, whether they retain their pathogenic characteristics in that environment, and whether they survive in quantities sufficient to be infectious and pathogenic for man are the critical but yet undetermined parameters.

It goes without saying that sewage treatment plants are one of the most important facilities devised by man to control infectious disease of human origin known today. The proper and adequate decontamination and disposal of human excreta are vital safeguards to human health, and extreme control measures have been adapted to insure human pathogens of fecal source do not contaminate drinking water supplies and, where possible, the environment.

Bacteria--

Bacteria have been estimated to compose 25-33 percent by weight of human feces (9). Although the greater portion of these bacteria are dead, a number of studies have shown that the viable organisms are a mixture of aerobic and anaerobic types. The exact numbers, genera, and species of the fecal mass cannot be absolutely stated because factors such as age and nutritional habits can readily alter the qualitative and quantitative characteristics of the normal fecal flora.

In general, anaerobic bacteria make up 99 percent of the fecal flora (10). Bacteroides, which are Gram-negative bacteria, and Bifidobacteria, which are Gram-positive, are the predominant anaerobes approximating numbers in the magnitude of $10^9 - 10^{10}$ per gram of feces. Lactobacillus, Clostridia, and fusobacteria average about $10^3 - 10^5$, enterobacteria 10^6, and enterococci 10^5 per gram. Other organisms such as Veillonellae, staphylococci, and yeasts are usually less than 10^3 per gram of feces. Less frequent are Proteus spp., Pseudomonas aerugenosa, Bacillus spp., and spirochetes.

Among the enterobacteria, Escherichia coli are the most common. Klebsiella and Enterobacter groups are found in feces of only a portion of healthy persons and are usually in small numbers (11).

Regarding the bacterial content of sewage, about $10^6 - 10^7$ organisms per ml can be recovered from sewage on standard nutrient media incubated at room temperature (20°C). The reduction in number of organisms on a per gram weight basis in sewage compared to that found in human excreta can be partially explained by dilution and partially by the fact that the more aerobic environment of the sewage favors destruction of the very oxygen-labile anaerobic organisms found in feces. The actual number of total organisms in sewage varies with seasonal changes, being greater in the summer months, and from one geographic region to another. The most prominent organisms found in sewage are members of the Proteus group, coliform bacilli, streptococci, anaerobic spore-forming bacilli, natural water bacteria, and denitrifying bacilli. In terms of expected numbers per ml of sewage, E. coli reach levels of 10^5 per ml, Streptococcus fecalis $10^3 - 10^4$, and Clostridia spp. $10^2 - 10^3$. Other organisms, including pathogenic salmonella and food-poisoning groups, can be found in crude sewage by use of selective growth media (9). Tubercle bacilli have also been recovered from sewage.

It is obvious that the bacteria which constitute the normal flora of the human gastrointestinal tract and the flora normally found in raw sewage are vastly different. The human gut is more compatible with the survival and growth of anaerobic organisms than is sewage, whereas the infrequently occurring Proteus spp. in human feces are a predominating species in sewage.

The admixture of human excrement and potable water has long been known to be a health hazard. In the early 1900's it was first recognized that the aerosol created by flowing wastewater may also be of public health concern. Horrocks (12) inoculated a sewer system with bacilli organisms and was able to recover those same organisms in the aerosol 15 meters above the wastewater level. He also recovered coliforms and Salmonella typhi in aerosol samples. Winslow (13) was concerned about the inhalation of sewer gas as a cause (or source) of typhoid. He showed that the splashing of sewage liberated organisms into the air and that these organisms could be recovered at some distance away from the source, but he did not believe these aerosols would be much of a health hazard.

There were other reports on the potential health hazard of aerosols emitted from sewage for over 20 years, yet the American Public Health Association Committee on Standard Methods for Examination of Air (14) reported in 1917 that in view of the small number of bacteria in air there did not seem to be any great sanitary significance of the aerosols emitted by sewage.

Then in 1934, Fair and Wells (15) using an air centrifuge determined that there were about 780 organisms per cubic meter of air adjacent to activated sludge aeration tanks and that nearly 140 organisms per cubic meter were detectable some distance away from the tanks. About 10 percent of these organisms were coliforms. These were perhaps the first quantitative and qualitative studies to be done and, although crude, did show the potential hazard of sewage aerosols for man. In view of the fact that the average person breathes about 20 cubic meters of air a day, the presence of even a few pathogenic organisms per cubic meter of air could represent an adequate exposure to an infectious agent, depending on the type of agent, the conditions of exposure, and the susceptibility status of the exposed person.

Several studies have been conducted to show the potential hazards of using wastewater for irrigation of land (16-18). Sepp (19,20) reviewed the public health aspects of this practice in Europe. In an extreme situation, Reploh and Handloser (16), using the insensitive method of agar settling plates, demonstrated that an aerosol created by spraying raw sewage onto crops contained coliform organisms that could be detected 0.4 km downwind when the wind velocity was 16-32 kph. Bringmann and Trolldenier (17) showed that spraying settled raw sewage disseminated organisms whose viability was dependent on the relative humidity, wind speed, and solar light exposure time. High humidity, high wind, and little sunlight accounted for widespread dissemination. Such factors as vegetation around the sewage plant origin of the aerosol were also factors, and depending on these variables several studies have shown that aerosols can be distributed from 3 to 1200 meters from the source. Shtarkas and Krasil'shchikov (18) studied the aerosol distribution created by sprinkler systems for wastewater aeration and they detected bacteria 0.5 km away and recommended a restricted residential zone of 1-km radius around such facilities.

Katzenelson and Teltsch (3) likewise examined the air in the vicinity of nondisinfected wastewater spray-irrigated fields. Coliforms were found at a distance 250 meters downwind from the irrigation line. In one case, salmonellae were isolated 60 meters from the source of irrigation.

An extensive examination of microbial pollution associated with the irrigation of wastewater has been conducted by Johnson and co-workers (21). In a Phase I report, total coliforms, fecal coliforms, bacilli, and viruses were detected at a distance of 1600 meters downwind from the source of the spray. An unexpected result was that wind speed and direction and effluent viable particle concentration did not seem to affect the total viable particle concentration in air. The best linear regression equation linked the airborne total coliform concentrations to distance, solar radiation, temperature, relative humidity, and atmospheric stability. Regression variables shown to have little effect were effluent coliform level, wind speed and direction, and length of sampling period.

In a different study of an activated sludge treatment plant, Johnson et al. (22) found the plant was a source of bacteria and viruses to the air. These agents were not detected above background levels at distances greater than 0.4 km from the plant site.

In general, three factors have been repeatedly shown to be involved in maintaining the viability of organisms in aerosols: 1) relative humidity, 2) solar light exposure, and 3) wind speed. High humidity favors most bacteria and some virus survival (see later). These factors have also been shown to be involved in organism viability in the field studies done to determine the possible health significance of microorganisms from sewage treatment plants. Solar light, particularly the ultraviolet light portion, is damaging to the genetic competence of bacteria and viruses and also has a desiccation effect. Wind speed was considered by Hickey and Reist (23) as reducing the transport time of viable organisms and thereby increasing survival and dissemination of infectious material.

Goff et al. (2) attempted to determine the relative importance of solar light on survival of aerosolized bacteria by comparing the viable counts of air samples collected during nighttime and daytime. Goff was not able to evaluate the relative importance of radiation, humidity, air temperature, or wind speed on viability of the aerosols. He suggested that solar light, low humidity, high temperature, and low wind speeds reduced the viability and/or dissemination of sewage aerosols.

However, Kenline (24) could find no relationship between relative humidity and die-off time and felt the facts were more complex. He believed dessication was the prime stress factor to viability of bacteria. For droplets that evaporated in less than 1 second a loss of viability was significant, but after this time die-off of residual organisms was slow and little influenced by solar light, humidity, or temperature.

Ladd (25) seeded Bacillus subtilis, spore forming bacteria, in a sewer intake 8 km away from a plant. Five to 10 hours later he could recover the same organism in aerosol samples collected downwind from the plant, but did not recover them upwind. He concluded that aerosols from treatment plants could be harmful to plant employees and residents in the adjacent areas. He suggested wastewater flow rates as a fourth variable affecting emission rates and distribution. Linear regression analysis indicated that viable particle emission rates increased slightly with increased wastewater flow rates. Ladd's results for all four parameters suggested:

1) emission rates decrease with increased air temperature except at the activated sludge tank where the higher air temperature increased the emissions;
2) as the air speed increased there was a decrease, or no change, in the viable particle count;
3) as the relative humidity increased the emission rate decreased.

Higgins (26) attempted to simulate aerosol emission in the laboratory to control for the variation introduced by environmental conditions. He inoculated coliforms, *Streptococci* spp., *Serratia marcescens*, and *Bacillus subtilis* into a water bath and aerated the bath to generate an aerosol. He found *S. marcescens* more frequently in the aerosol than the other organisms. He concluded that those organisms most concentrated at the surface of the bath were the more likely to be present in the aerosol. He also found that the size of the aerosol particles was important in determining the type of organism recovered. *Aerobacter aerogenes* was present in only large particles, whereas *S. marcescens* was present 20 times more often in small particles.

Another variable that should be considered in the dissemination of viable organisms in the aerosol is that of updrafts occurring over the wastewater tank sites. Imhoff and Fair (27) and Halvorson et al. (28) showed that when the air temperature is at, or below, the temperature of the wastewater there is proportionately more updraft and consequently more mobilization of the aerosol. Albrecht (29) plotted downwind *E. coli* recoveries as a function of updraft and wind velocity and showed that a positive relationship did in fact occur. In contrast, Kenline (24) found fewer organisms 1.5-2.5 meters above ground than at ground level.

Compared to other types of operations in sewage treatment plants, Napolitano and Rowe (8) found aeration tanks to be the major source of viable aerosols. They estimated that 50 percent of the particles emitted were less than 5 μm in diameter which are the particle sizes most likely to enter the upper and lower respiratory and gastrointestinal tract of man and therefore pose a health hazard.

In terms of health hazards, particle size is often referred to as a critical characteristic for potential pathogenicity. This is the basis for using the Andersen cascade air sampler (30) to measure viable particle concentrations according to particle size. However, it cannot be ignored that all size particles containing microorganisms could contaminate man's environment and ultimately be a source of exposure via fingers, flies, food, or fomites. The increased hazard due to particle size of 5 μm or less refers specifically to direct inhalation or ingestion and does not consider possible exposure by indirect contact with the "Four F's" mentioned above.

Randall and Ledbetter (7) examined ways of collecting aerosol samples and determined that the All-Glass-Impinger (AGI) detected more organisms (4×10^4 colonies/m^3 of air) under a given set of conditions than did the Andersen sampler (3.1×10^4 colonies/m^3) or the agar settling plate (7.8×10^3 colonies/m^3). The qualitative differences in these different samples were mainly in the number of non-enterobacteria types recovered. Approximately 10 percent of all organisms identified were *Klebsiella*, *Aerobacter*, and *Proteus* spp., which are mostly respiratory organisms, and a few Providence group, but no *Salmonellae* or *Shigellae*.

Randall and Ledbetter (7) recommended Klebsiella organisms be used as an indicator of sewage emissions for potentially hazardous particles in the air. They detected immediately adjacent to the aeration tanks both capsulated and non-capsulated forms of Klebsiella and proposed that the capsulated forms would be the more stable forms in aerosols. This is one of the few studies that has considered not only the presence of a species of bacteria in aerosols, but also the potential pathogenic characteristics of the organism, i.e., capsule formation. These characteristics are retained even after aerosolization.

Sorber et al. (31) studied the aerosols produced during spray irrigation of wastewater and found that about half of the coliforms present in droplets were Klebsiella spp. This organism, some species of which are human pathogens, were most frequently associated with small (1.1 µm) droplets which have a high probability of inhalation and retention by man. They did not specifically state, as did Randall and Ledbetter (7), that these should be the index organisms of environmental air.

Adams and Spendlove (1) investigated the coliform and total bacteria aerosols generated from trickling filter plants. Positive recoveries of coliform organisms were made at night up to a distance of 1.3 km from the source.

Aerosols from activated sludge units have been determined by King et al. (5) and Pereira and Benjaminson (32). King et al. found that Bacillus spp. were the predominating organism, followed by Alcaligenes faecalis. A total of 41 different microorganisms were identified. The colony counts obtained were affected by temperature and relative humidity but not wind speed. Pereira and Benjaminson identified 10 different microorganisms in the air around the plant. The maximum distance from the plant sampled was 300 meters downwind. Their findings were in agreement with Randall and Ledbetter and thus they also recommended that Klebsiella would serve as the best indicator of bacterial air pollution from sewage sources.

Of interest are the findings of Blanchard and Syzdek (33,34) that the concentration of S. marcescens in droplets formed by bursting bubbles was 10-10,000 times greater than in sewage itself (on a per volume basis). The number of organisms in the droplets increased as the drop size increased, and the number decreased as the number in the sewage decreased. However, Higgins (26) had not found such a relationship, nor could he show that air temperature, water temperature, or relative humidity were critical factors regarding particle size or numbers from bubbling wastewater. Most importantly, he demonstrated that particle size was dependent on the concentration of solids in wastewater; the higher the solids concentration, the larger the particle size.

Smith (35) extended these concepts experimentally using spores of Bacillus subtilis to simulate and monitor viable particles. He showed that the number of B. subtilis aerosolized increased as the number of spores in the wastewater increased up to a concentration of 1 spore per aerosol droplet. After this concentration was reached in the aerosol droplet it did not increase even though the concentration of spores in the wastewater increased. Smith also found that the number of spores aerosolized was influenced by the concentration of salts and organic chemicals in the sewage; the more salts and organic chemicals present in the wastewater, the more spores were found in the aerosol.

It is not yet clear from the literature what the complete spectrum of bacterial organisms is in aerosols originating from sewage. Possibly, a reason for this is the multitude of meteorological, environmental, sampling, and cultural variables involved in the survival and recovery of a large variety of organisms. A number of investigators have recovered enterobacteria at variable distances away from sewage treatment sites (23), whereas other investigators have not (21). The implication of finding enterobacteria, whether they are pathogenic or not, is that they are indicators for the presence of human pathogens which, though present in smaller numbers, are more hazardous to man's health. In spite of the fact that some investigators have identified enterobacteria in sewage aerosols, there is only one study that has attempted to show that pathogenic strains or variants of bacteria can occur in aerosols. The study of Randall and Ledbetter (7) showed that pathogenic organisms may have a selective advantage for survival in aerosols because of the nature of the characteristic endowing the pathogenic property.

In summary, the potential groups of organisms that have been reported to be recovered from aerosols include: Klebsiella, Aerobacter, Proteus, Staphylococcus, hemolytic Streptococci, and Mycobacteria, not to mention other organisms that are considered non-pathogenic except in opportunistic situations.

Virus--

Viruses are not considered part of the normal flora of the human intestinal tract although several enteroviruses (polio-, coxsackie-, and Echoviruses) have been recovered from apparently healthy individuals undergoing subclinical, or inapparent, infections. The enteroviruses are the most frequently reported viral agents found in raw sewage but recovery is not regular. Mack et al. (36) reported recovering one or more enteroviruses in one of every 12 samples collected daily over a 2-year period. Sewage is however an excellent source of bacterial viruses.

A number of investigators (1,37,38) have suggested that human viruses in sewage may be even more of a threat to human health than bacterial agents, therefore, viruses deserve more intensive study. Clarke et al. (39) calculated that domestic sewage may contain 7,000 infectious virus particles per liter. This quantity probably decreases 90 percent in the processing of sewage prior to chlorination (36,40,44). Presumably the 90 percent loss is due to bacterial "killing" of the infectious particles because it occurs mostly under aerobic conditions. Another mode of virus inactivation is by ingestion of viruses by protozoa in sewage (45). In addition, Slote (38) has proposed that the loss could be due to escape of virus particles in aerosolized particles. According to Morrow's work (46) on Foot and Mouth Disease virus (an enterovirus), a single aerosolized particle 0.1 mm in diameter could contain as many as 10 infectious virus particles. Baylor et al. (47) showed that bacterial viruses, as well as E. coli, can be concentrated 50 and 30 times, respectively, in droplets compared to the concentration in the liquid phase. Malina et al. (48) recently showed that about 25 percent of all the poliovirus in sewage was associated with the sludge, and survival time of the virus is inversely related to the amount of solids present in the sewage. Thus, in addition to "killing" viruses in sewage they may be lost by bubble formation in sewage treatment or associated with the solids and not available for incorporation into aerosol droplets.

Berg (49) stated that there are over 100 different enteroviruses present in sewage. Johnson et al. (21) analysed sewage samples and found 80 percent of viruses isolated were enteroviruses and the remainder were adenoviruses and reovirus-like agents. In raw sewage Nupen (50) recovered 20,000 infectious virus units per liter, most of which were entero- and adenoviruses. Chang (51) reported that over 30 types of coxsackieviruses could be identified in sewage. Several studies have reported polio (wild and vaccine types), Coxsackie virus A16, Coxsackie virus B and Echoviruses to be present in sewage (52-54).

In a theoretical assessment of the virus hazard associated with spray irrigation of sewage, based on laboratory studies and effluent data, Sorber et al. (37) calculated that workers 200 meters downwind of the source could inhale 20 infectious airborne viruses in 10 minutes. The dissemination of viruses by spray irrigation of wastewater effluent was reported by Teltsch and Katzenelson (55). They recovered Echovirus 7 in four of 12 air samples collected 40 meters downwind from the sprinkler.

The presence of airborne coliphage at the edge and within 15 meters of activated sludge and trickling filter plants has been established by Fannin et al. (56). The coliphages were enumerated by a most-probable-number (MPN) procedure. Average emission levels from trickling filters and activated sludge units were 2.84×10^{-1} and 3.02×10^{-1} MPN coliphage/m^3 air, respectively, for all positive observations. No correlation could be found between bacteriophage isolations and wind speed or temperature. Relative humidity was significantly correlated. The authors stated that modification of the procedures used will enable collection and identification of the animal virus levels in sewage emissions. This study was extended when Fannin et al. (57) demonstrated that coliphage are more stable than coliforms in an airborne state.

Several experimental studies have demonstrated the probable effect of relative humidity on survival of viruses in aerosols (58-66). Lipid-containing viruses usually survive better at low relative humidity (58-66), while those containing only protein and nucleic acid but no lipid survive better at a high relative humidity (59,62,63). Several investigators (68-70) have suggested that loss of viral infectivity in aerosolized particles is due to dehydration and concurrent presence of toxic substances in the aerosols.

Reviewing the literature on viruses in sewage and aerosols raises the obvious suspicion that human viruses other than those in the enterovirus group may be present in sewage aerosols. Subrahmanyan (53) recently suggested infectious hepatitis virus may survive similarly to enteroviruses in sewage and be of public health concern. Such other viruses may cause illnesses that would require epidemiological studies for lack of virological methods to isolate and identify these agents in environmental or clinical specimens directly.

Fungi--

The presence of fungi, particularly human pathogenic fungi, in sewage and aerosols has not been adequately studied. A potential threat of fungi in aerosols to human health is recognized because many are spore-formers which survive very well in an adverse environment and are commonly spread by the airborne route to man; i.e., histoplasmosis, coccidioidomycosis, blastomycosis, and cryptomycosis.

In 1964 Dixon and McCabe (71) stated that pathogenic fungi can be isolated from sewage, but because of the low morbidity of mycotic diseases in man they did not believe fungi in sewage could be a significant health hazard.

Sayer et al. (72) made estimates of airborne fungal flora by use of the Andersen sampler and gravity settling plates; the former was much superior both quantitatively and qualitatively. The majority of the sampling was done in hospital rooms and operating suites, while other sampling locations were undefined. Although they reported Hormodendicum, Penicillium, Aspergillus, and Saccharomyces groups as the predominant spore-forming fungi present, they also found minor numbers of several potentially pathogenic fungi. They did not state, however, whether these fungi could be expected in all types of air samples, nor did they discuss possible sources of these fungi.

Non-Viable Particles and Gases

Non-viable particles and gases emitted from sewage treatment plants could also be a health hazard but this possibility has not been addressed. Only one substance, mercury, has been studied in relation to emissions from sewage treatment facilities (73). Sewage treatment was found to be a source of airborne organic mercury as well as elemental mercury, and the concentration of organic mercury in emissions appeared to be related to sewage volume of the plant rather than industrial contamination.

Ammonia is the prevailing form of nitrogen in the effluent of activated sludge facilities, and loss of ammonia by emission from tank surfaces has been found in laboratory studies to be highly efficient depending on pH, wind velocities, and detention time (74).

In addition to non-viable emissions, the background or ambient concentration of non-viable particles and gases in the vicinity of the sewage treatment plant may also be an important consideration when examining the emission of viable organisms. Several studies have shown that correlations exist between viable microorganisms and air pollutants in the ambient air. Lee et al. (75) found significant positive correlations between bacteria and concentrations of NO, NO_2, and hydrocarbons and significant negative correlations with SO_2 and CO when temperature and humidity were held constant. No correlations were found between bacteria concentration and temperature, relative humidity, or concentration of total suspended particulates. Mancinelli and Schulls (76) found significant positive correlation between the number of viable bacteria isolated from air samples and the concentrations of NO_2 and total suspended particulates and a significantly negative correlation with NO concentration. No correlations were found with SO_2 and hydrocarbon concentrations, temperature, and relative humidity. Comparisons between these studies are difficult due to the different methodologies used. The relationship between ambient pollutant levels and bacterial concentration clearly needs further investigation.

Epidemiological Studies

There have not been adequate epidemiological studies of the health hazard of sewage treatment plants to a community. A number of investigators studying the viable particles in aerosols of sewage have recommended such studies. The concern that sewage emissions may be hazardous mainly stems from the fact that respiratory and enteric bacteria can be recovered from aerosols some distance downwind from the plant site. Even though not all the recoverable agents are pathogenic for man they serve as indices that infectious and pathogenic agents could be present.

The question whether pathogenic bacteria can survive in aerosols as well as non-pathogenic agents has not often been considered. Randall and Ledbetter (7) did recover *Klebsiella* spp. from sewage aerosols and some of these isolates were capsulated forms which are considered pathogenic. It was of interest that these workers also found that the capsular forms were more stable in the aerosol environment than the non-capsulated forms. Even so, Randall and Ledbetter did not consider these to be a health hazard. Based on the numbers of *Klebsiella* spp. they recovered from the aerosol at sewage treatment plant sites, they calculated that a plant worker would inhale about 100,000 organisms per month. From studies in monkeys it was shown that a critical dose of 800,000 pathogenic *Klebsiella* could cause respiratory tract disease (9).

The concept introduced above is important. Not only are the genera, species, and pathogenic characteristics of bacteria in aerosols important, but also the number must be sufficient to be hazardous to man. There is no uniform number of bacteria necessary to cause disease. The dose size varies with the pathogen. For example, less than 100 shigella organisms can cause shigellosis, but it requires 100,000 *Salmonella typhi* to cause typhoid fever and over 100 million *E. coli* or *Vibrio cholera* organisms to cause diarrhea or cholera, respectively (77).

Viruses in aerosols have been less well studied mainly for technical and monetary limitations in doing such studies. These agents are considered to be important health hazards in aerosols partly because as few as one infectious virus particle could be required to initiate infection (78-81) and partly because small doses of viruses in aerosols are more likely to cause inapparent infections than are small doses of bacteria (82).

Ledbetter et al. (83) have reported an epidemiological type of study regarding the health hazard of sewage aerosols. They compared the number of respiratory illnesses reported by sewage plant workers with those reported by water treatment plant workers. They found that the number of cases of pneumonia in both groups was nearly the same, but the sewage plant workers had more colds: 1.62 colds/sewage worker/year versus 1.27 colds/waterworker/year, and sewage plant workers had more "flu": 7.7 cases/100 sewage plant workers/year versus 5.1 cases/100 water treatment plant workers/year. The significance of these data was not determined. It has been suggested (23) that new employees would be more susceptible to viable aerosol infections than experienced personnel, that the socioeconomic status of the sewage and water plant workers may not be the same, and that the non-viable particle composition of the atmosphere at each plant is probably different.

There are four recent reports that have attempted to address the question of the health effects of particles produced during wastewater spray irrigation or sewage treatment. Katzenelson et al. (84), based on a retrospective study of incidence of enteric diseases in 77 kibbutzim, found the incidence of shigellosis, salmonellosis, typhoid fever, and infectious hepatitis were two to four times higher in communities practicing wastewater irrigation than those not. The association of the aerosols and illness was strengthened by the finding that the difference in incidence rates was not significant in the non-irrigation season. However, the residential areas were 100 to 3000 meters distant from the irrigated fields, leading to the possibility that transmission could be by body or clothing of the workers returning to their homes.

Rylander et al. (85) observed sporadic outbreaks of fever, malaise, and eye symptoms in newly employed sewage workers. About 50 percent of the workers exposed to dust from pulverized sludge had these symptoms. Although the evidence was indirect, the investigators suggested that endotoxins were the responsible agents for these conditions.

R.B. Dean (86), in a report to EPA, translated and commented on Danish studies of absenteeism and death rates among sewage workers in Denmark. In workers over 50 years of age, absenteeism was significantly greater than in office workers of the same age. Reports of gastrointestinal and chronic conditions were the most frequent reasons for absenteeism. The death rate in sewage workers was greater in those working 9-16 years at several plants than in those employed less than 9 years. The strength of these associations will depend on further analytical data and demographic characterization of the workers.

Johnson et al. (22) found little evidence that viable particles originating from an activated sludge plant were disseminated more than 0.4 km into the surrounding area. A health survey of households within a 5-km radius of the plant was conducted, and Johnson was not able to observe any significant illness occurrence. This is one of the first studies to demonstrate that sewage treatment plants may not be hazardous to households more distant than 0.4 km from the plant.

Dowling (87) made the interesting observation that persons exposed to sewage aerosols may develop immunity by being regularly exposed to low levels of viruses that cause infections but not clinical illness. Such an immune person would have fewer clinically evident infections than persons sporadically exposed who have had less chance of developing immunity, and therefore would have more clinical infections. Clark compared the antibody levels of highway maintenance workers and sewage treatment plant workers in Cincinnati for more than 30 enteroviruses. The sewage workers, in general, had higher antibody levels than the highway workers for three enteroviruses (personal communication: C. Scott Clark, Department of Environmental Health, University of Cincinnati, Ohio, February 26, 1979).

In summary, an attempt has been made here to show that there is an abundance of literature documenting that bacteria and viruses survive in sewage and are emitted as aerosols. It is apparent that survival and distribution of these viable particles in air are dependent on a multitude of interacting factors. This has raised many questions about viable particles being even potentially hazardous to man. Little information is available concerning the presence of non-viable particles, gases, and fungi in sewage and aerosols, and the possibility that these alter man's health directly, or indirectly, cannot be discussed. Epidemiological studies of sewage-aerosol-exposed populations would be an obvious way of determining the health effects of these exposures, but health studies in communities adjacent to plants have seldom been proposed because of the complexity of the confounding factors of relating environmental measures and health of a presumably exposed population.

SECTION 2

CONCLUSIONS

1. The sewage treatment plant was a source of airborne total viable particles (total aerobic bacteria-containing particles) and total coliform bacteria as measured in the community.

2. The concentration profiles of trace metals, particulates, nitrates, sulfates, sulfur dioxide, nitrogen dioxide, hydrogen sulfide, and chlorine in the community indicated that the plant was not a source of these materials.

3. Ambient concentrations of total viable particles and total coliform bacteria showed no obvious correlation with plant operating characteristics or sewage concentrations.

4. Total viable particle and total coliform bacteria concentrations did not display obvious trends with solar radiation, temperature, and relative humidity.

5. Virus and coliphage measurements in sewage and air were inadequate in number to determine their concentrations with any confidence.

6. Significant linear relationships were not found by regression analyses of total viable particle exposure indices and the following health measurements:

    a) self-reported acute illness rates
    b) pathogenic bacteria isolation rates
    c) prevalence rates of antibody to certain enteroviruses
    d) virus antibody titers

SECTION 3

RECOMMENDATIONS

Based on this study the following recommendations can be offered:

1. Preliminary environmental sampling in the community should be conducted to determine that a sufficient number of people live in the high exposure area to provide an adequate random sample size for epidemiological evaluation. The number of people living in the high exposure area will likely always be problematical, and comparable studies of several plants may be necessary.

2. A survey of the study population should be conducted with a questionnaire that would provide demographic, occupation, income, education, and length of residence information and minimize inquiry of previous acute and chronic illness.

3. The health watch population should be a subsample of the questionnaire population, and the subsample should include all households in the high exposure area with an equivalent number of households in the medium and low exposure areas.

4. Blood samples for serological measurements should be obtained at the onset of the study and at 6-month intervals for the duration of the study from all health watch participants. Of all laboratory data possible to collect as measurements of infection, serosurveys are most reliable and conducive to epidemiological interpretation.

5. Using the monitoring and analysis techniques developed in this study, studies of sewage treatment plants should be conducted to evaluate the relative emission characteristics of other plant designs. The results reported in this study indicate that plant design can have a significant effect on viable emissions. Viable particle concentrations in air reported in the literature at trickling filter plants and at treatment plants with different aeration characteristics and sludge processing facilities at the same site have been found to be generally higher than those found at this plant.

6. Health and environmental monitoring should be conducted for a minimum of one year.

7. Further research into sampling techniques of airborne coliphage and animal virus should be carried out to develop reliable methods for

quantitation before they are included in a monitoring program for an epidemiological study.

8. Identification of bacteria recovered from samples should be done for at least a subset of the air samples.

9. Recommendations specifically regarding a health watch study are:

    a) Use public health nurses to do both the interviewing and health watch recruiting. The nurses' familiarity with the necessary clinical specimens would allow a more convincing explanation to be offered and consequently a higher acceptance rate.
    b) The nurses should be very well paid as this type of work is very demanding. The nurses should also be under contract for the entire study period.
    c) One nurse should be the primary contact for each family, from the initial interview to the completion of the final diary.
    d) The recruitment period should be extended so that non-participants can be replaced. Families should not be counted as health watch participants until they have turned in a diary or donated a clinical specimen.
    e) Children should be given rewards each time they give a specimen, rather than delaying their gratification until the study ends.

SECTION 4

METHODS OF PROCEDURE

STUDY AREA

Selection of Site

During the initial planning stages of this study several wastewater treatment plants in the Chicago area were considered as candidate sites for a sewage health effects study. Most important consideration was given to:

1) the presence of a sizeable and homogeneous (socio-economic status) population within a 1.6-km (1-mile) radius of the plant;
2) the relative size of high-risk population groups, i.e., children and elderly, residing near the plant;
3) source of sewage, whether domestic or industrial;
4) the predominant wind patterns for the plant area in relationship to the residential population areas;
5) the topography of the plant area.

After thorough consideration of all these factors, the North Side Sewage Treatment Works (NSSTW) in Skokie, Illinois was selected for study. The plant is nearly surrounded by a substantial number of residences. Census information (1970) indicated the population to be of homogeneous socio-economic status and to consist of appropriate numbers of individuals in the desired high-risk age groups. The sewage is not heavily industrial, and the prevailing wind patterns and topography appeared to be conducive to exposure of population groups.

Description of Plant

Built in 1929, the NSSTW is one of the three main plants of the Metropolitan Sanitary District of Greater Chicago (MSD). The plant is located on Howard Street between Hamlin Avenue and McCormick Boulevard in Skokie, Illinois (Figure 1) which is a northwest suburb of Chicago.

The NSSTW is an activated sludge plant employing diffused aeration with a little tapered aeration. Chlorination occurs after the final settling process. No sludge processing occurs at the plant. A schematic of the plant is shown in Figure 2. The maximum capacity of the plant is 1.51 x 10^9 liters of raw sewage per day. During the study period (April-November, 1977) the plant had an average daily flow rate of 1.1 x 10^9 liters of sewage and a median air rate of 4.6 x 10^6 m^3/day. The estimated surface area of sewage in the aeration tanks is about 55,000 m^2 in settling tanks, concentration tanks, etc., exposed to the atmosphere. The total retention

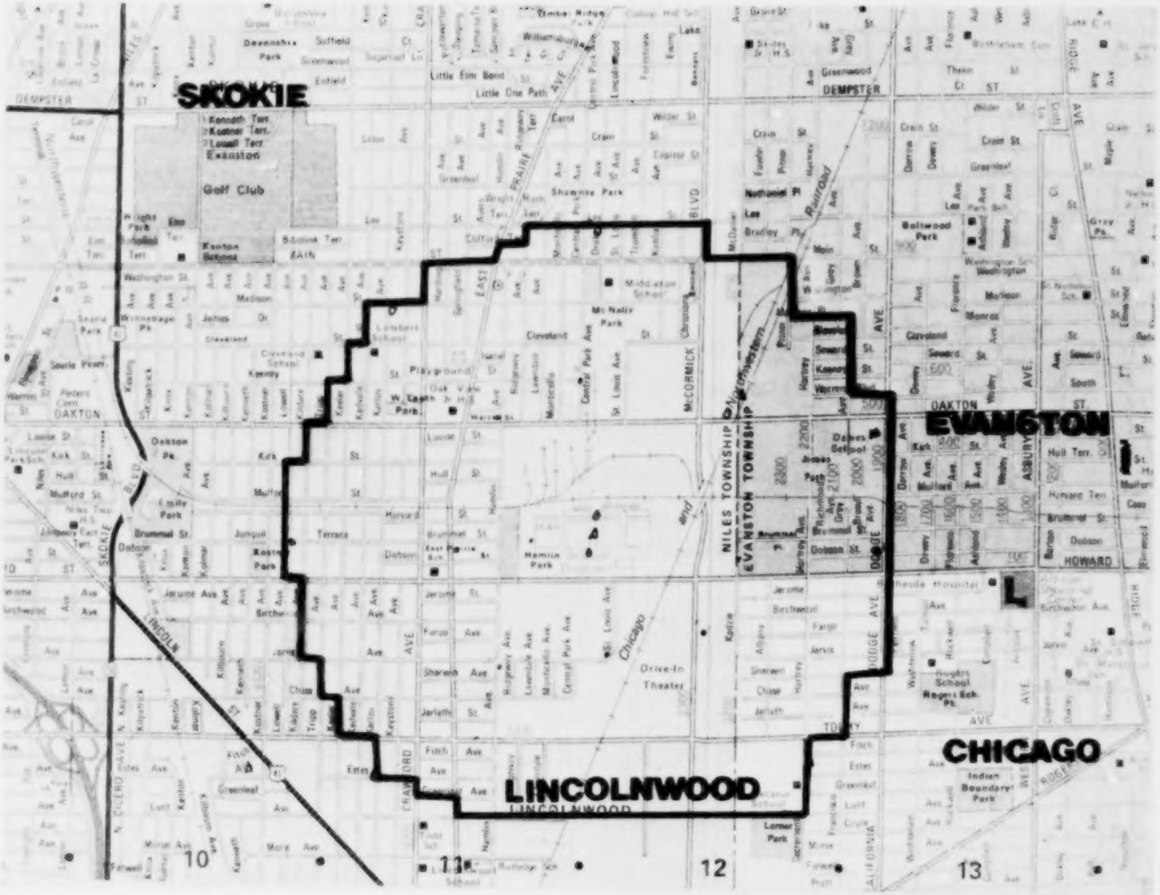
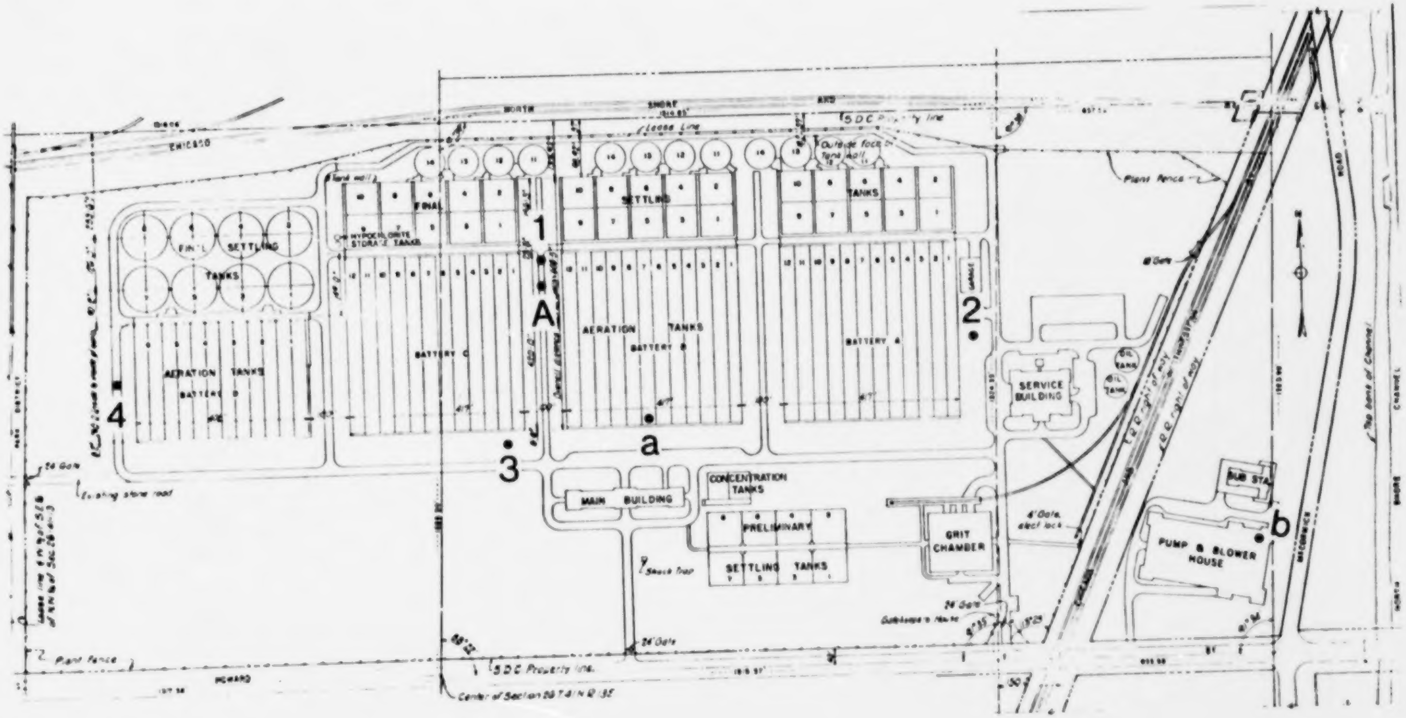


Figure 1. Map of study area.



Sites 1-4 are for sampling of airborne viable constituents.
Site A is for sampling of airborne non-viable constituents.
Sites a and b are points for grab samples of sewage for analysis of viable and non-viable constituents.

Figure 2. Schematic of North Side Sewage Treatment Works with on-plant sampling sites.

volume of one battery of aeration tanks is 7.45 x 10^4 m^3. The tank levels are maintained at approximately 4.6 meters. Residence time of sewage in the aeration tanks is generally 5½ hours.

Description of Study Area

The area within a 1.6-km radius of the treatment plant as shown in Figure 1 was designated as the study area. Previous studies have found that the dispersion of viable particles does not exceed 0.8 km from the source. Therefore, the 1.6-km radius study area permitted analysis of exposed and unexposed populations. The study area included portions of four communities: Skokie, Lincolnwood, Evanston, and Chicago. As can be seen in Figure 1, the plant is located in a small industrial area. Light industries are situated north, east, and south of the plant, occupying most of the land within the first 0.4-km (¼-mile) radius of the plant. Residences are located about 152 meters west of the aeration basins, about 427 meters southwest of the basins, and about 0.8 km (½ mile) directly east of the tanks. Housing also exists within 0.8 km north and south of the plant. The major residential section begins at the 0.4-km radius line and extends uniformly through the 1.6-km radius area.

The population of the study area was estimated to be 15,850 persons, or 5,600 households, based on the 1970 census. TABLE 1 presents some characteristics for the population living in the study area. Considering property value, age, and race, the population appeared to be relatively homogeneous. Although there were differences in several characteristics between some of the tracts, these 1970 figures were used for preliminary evaluation of the population and not for subsequent demographic analysis.

TABLE 1. 1970 POPULATION CHARACTERISTICS OF CENSUS TRACTS INCLUDING ONLY THOSE BLOCKS WITHIN 1.6-KM RADIUS OF PLANT SITE

Census tract:	8072	8074	8075	8076	8080	202	203	8103
1970 population	999	589	3363	5067	2072	3366	2068	2029
No. of blacks	-	-	5	7	2	4	-	4
% under 18 yrs.	34	30	30	32	30	26	10	25
% 18-61 yrs.	59	55	58	60	60	63	64	62
% 62 yrs. and over	7	15	12	8	10	11	26	13
% housing units rented	8	9	5	5	3	3	-	12
Ave. value of owned homes ($)	36,000	37,000	35,000	33,400	43,500	35,400	35,400	28,000

METHODOLOGY

Health Questionnaire Survey

Community Relations Work--

During the fall of 1976, meetings were held with the village managers of Skokie and Lincolnwood and with the Director of the Skokie Health Department. The project was explained in full and was endorsed by both communities. The local officials also understood the need for explaining the study only as an air quality study, rather than as one of a sewage treatment plant, to avoid biasing the illness reporting. Throughout the project, both municipalities were extremely generous in making facilities and resources available and in helping solve various local problems.

The Public Relations Department at the University of Illinois sent a publicity release describing the project to the local newspapers. However, none of the papers published the announcement. The Skokie Village Report (circulation 25,000) did carry an announcement of the project, expressing the support of the Village, and urging residents to cooperate. This article was published on March 29, 1977, approximately 1 week before the interviewers began the field work. Copies of the article were given to the interviewers for use in their introduction and explanation of the project to the families.

Finally, advance letters were sent to all families in the questionnaire sample. This letter arrived several days prior to the interview; it explained the purpose of the study and invited residents to call the field coordinator if they had any doubts about the authenticity of the project.

Instrument--

Design--A history of the baseline health status of each participant was tabulated in a health questionnaire developed in collaboration with Survey Research Laboratory (University of Illinois, Circle Campus). Specific questions were asked regarding any acute illnesses the participant had experienced in the past year. Additional questions were asked about such factors as chronic diseases, smoking habits, demographic characteristics (i.e., age, sex, race, income, occupation), length of residence in the study area, travel, and vaccination history.

Pretest--Twenty-four households were selected for the pretest; 17 interviews were completed, three households could not be contacted after six attempts, three households refused, and one address was non-existent. After administration of the questionnaire, the interviewers were debriefed and their suggestions were incorporated into the final questionnaire, though very few modifications were made.

Sampling--

Definition of sampling zones--An important requirement for this study was that the sample of households be equally distributed throughout the study area. Therefore, three concentric sampling zones (Figure 3) were designated around the sewage treatment plant as follows:

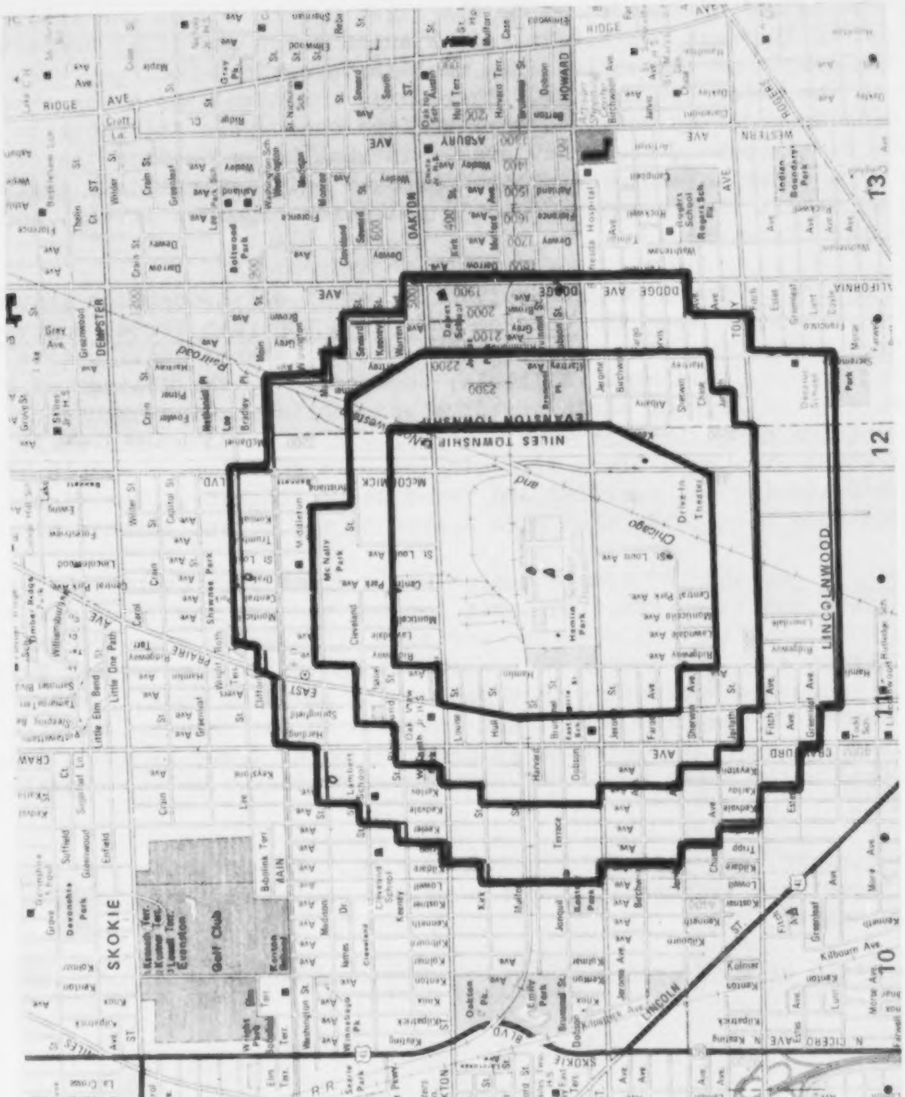


Figure 3. Map of sampling zones.

Sampling Zone 1: 0.0-0.8 km from center of plant
Sampling Zone 2: 0.8-1.2 km from center of plant
Sampling Zone 3: 1.2-1.6 km from center of plant

Since the number of residences in the first 0.8-km radius was small (394) compared to the next two 0.4-km radius areas (1308 and 3630, respectively), a random sample of the entire area would have established many more households in the outer 0.8-km area. Therefore, a random sample was chosen for each zone in order to obtain a more uniform geographic distribution of households throughout the study area. It must be emphasized that these zones were established for sampling purposes only. Final data analyses were based on actual viable and non-viable pollution exposure levels, and not geographic distances.

Sampling frame--A comprehensive listing of all households in the study area was developed from the Chicago and North Suburban Street Address Directory (R.R. Donnelley & Sons, Co.) and a printer's mailing list (Nelson Printing Company, Glenview, Illinois; contracted by the Village of Skokie to provide all mailings of administrative and public service nature). Apartment building listings were personally enumerated by the staff as were blocks where printer's lists were missing. In addition, a sample of the printer's listing was verified and found to be accurate. The final listing included more households than were listed in the street address directory.

Sample design--The sample design was a disproportionate stratified sample with the three sampling zones forming the strata. Since an equal number of households was required per zone, the sample size for each zone was determined by the number of households in the smallest zone, Sampling Zone 1. Only 394 households were present in Sampling Zone 1; thus, nearly every family in Sampling Zone 1 was included in the sample. An equal number of households was then selected in Sampling Zones 2 and 3, since selecting additional units there would not have added precision to the overall results.

Therefore, allowing for non-cooperation, 332 units per sampling zone were chosen by a systematic random sampling procedure from the list of housing units.

$$\text{Probability of selection} = \frac{\text{number of housing units selected per zone}}{\text{estimated number of housing units per zone}}$$

$$\text{Zone 1} = \frac{332}{394} = 0.843$$

$$\text{Zone 2} = \frac{332}{1308} = 0.254$$

$$\text{Zone 3} = \frac{332}{3630} = 0.091$$

This means that 84, 25, and 9 of every 100 households in Sampling Zones 1, 2, and 3, respectively, were to be included in the sample. It is re-emphasized that incorporating more households from Sampling Zones 2 and 3 would not have improved the precision of the results since the small number of households in Sampling Zone 1 was the limiting parameter.

Administration of Questionnaire--

Interviewers for the survey were hired from the study area or nearby suburbs in order to improve the acceptance of the interviewer by the families. Twenty-three interviewers were trained in a 3-day session by Survey Research Laboratory and School of Public Health project staff. These training sessions instructed the interviewers in basic interviewing skills and background information about the project. The emphasis was placed on this being an "Air Quality and Community Health" study, rather than a "Health Effects of Sewage Aerosols" project to avoid biasing the participants' response as much as possible.

All interviews were conducted in the home of the respondent. If a family refused at the initial contact, a second (different) interviewer contacted the family. When the family refused again, this was considered a refusal and was the final disposition of the household. Six attempts were made to contact a family before designating that family as a "non-contact". Business addresses and addresses outside the study area were coded as incorrect addresses. (See TABLE 2 for a summary of questionnaire contacts). The average length of the interview was 45 minutes.

TABLE 2. SUMMARY OF QUESTIONNAIRE CONTACTS

Eligible households	No.	%
Completed interviews	807	81.0
Refusals	144	14.0
Non-contacts (no one home after six attempts; family on vacation for entire interviewing period)	29	3.0
Incorrect address (business address, outside study area)	16	2.0
Total sample size	996	100.0

As shown in TABLE 2, the overall acceptance rate of 81 percent provided the necessary number of households for the study. The percentage agreeing to participate was nearly equal in each zone:

Households Interviewed

	No.	%
Zone 1	269	81.0
Zone 2	267	80.0
Zone 3	271	82.0
Total	807	81.0

Data Reduction and Processing--

Responses to each question in the instrument were numerically coded for recording onto computer tapes. Coding, keypunching, and verification were performed by Survey Research Laboratory personnel. Data were arranged into SPSS (Statistical Package for the Social Sciences) format for retrieval and analysis.

Health Watch

Introduction--

In order to obtain ongoing, prospective information about health in the study population, a subsample of the persons interviewed in the Health Questionnaire Survey was solicited into the Health Watch. Participants, as family units, were asked first to maintain a health diary to self-report any and all illnesses they encountered for an 8-month period. Secondly, they were requested to provide blood samples at the beginning and again at the end of the 8-month period, and finally, families with young children were asked to provide clinical specimens, i.e., throat and/or stool specimens, for biweekly microbiological surveillance.

Recruitment of Households--

Recruitment into the Health Watch was attempted after a designated family had completed the health questionnaire. The interviewers were specially trained to explain the Health Watch and to encourage participation. The type of specimens requested from each family was dependent on the age structure of the household:

1) If children 12 years or younger were present, biweekly throat and stool specimens were requested from the children, as well as two blood samples and diary upkeep. The next older person over 12 years of age in those households was requested to provide only a stool specimen biweekly. All persons over 6 years of age were requested to give two blood samples and to maintain the diary.
2) If all persons in the household were over 12 years of age, two blood samples and dairy maintenance were requested from each household member.

Each Health Watch participant signed an informed consent statement delineating specifically what each person was agreeing to and what the overall purpose of the study was. All persons who completed the Health Watch were given a check for $10.00 as a token of appreciation.

Because it was difficult to predict actual compliance with these requests, the interviewers were instructed to accept families who would participate at any level, i.e., if a family would only keep the diary and not give blood, that family was accepted. Or, if a child would give only throat specimens, not stools, that was acceptable also. Thus, the range of participation varied widely among households.

Initially, the decision had to be made as to who should do the recruiting. The possibilities were:

1) to start with experienced interviewers and train them to do the recruiting into the Health Watch;
2) to start with trained public health nurses and train them in interviewing techniques; or
3) to proceed in a two-phased manner, with trained interviewers to administer the questionnaire, followed a day or two later by public health nurses to do the recruitment.

The third choice was eliminated because the families might lose interest during a 2-day lag period, and because of logistic problems coordinating the two sets of field workers. The second choice was highly favored, but was very expensive and logistically impossible, as 23 nurses would have been needed to complete the interviewing and recruiting in the alloted time (1 month). It was impossible to locate a contingent of 23 nurses to work for only 1 month. Interviewers who could be trained in Health Watch terminology were the most readily available and least costly method of recruitment. Therefore, these interviewers were utilized, but this was not an effective recruitment scheme.

Study Design and Sampling--

The study design and sampling for the Health Watch were extensions of the design and sampling methods described for the Health Questionnaire Survey. It was estimated that 300 households were needed to participate in the Health Watch in order to have sufficient health-related data to analyze. Consequently, 365 households (approximately 125 per zone) were selected as the sample in order to achieve an actual participation of 300 households. The probability of a household's selection for the Health Watch from the total number of households in each zone was:

$$\text{Zone 1} = \frac{332}{394} \times \frac{125}{332} = 0.318$$

$$\text{Zone 2} = \frac{332}{1308} \times \frac{125}{332} = 0.096$$

$$\text{Zone 3} = \frac{332}{3630} \times \frac{125}{332} = 0.034$$

However, these probabilities of selection apply only to the initially designated Health Watch subsample. A system was instituted to replace any initially designated Health Watch household that refused to participate. The replacement was the nearest (geographically) housing unit in the questionnaire sample.

The goal of recruiting 300 participating families was initially met; 365 families were recruited and agreed to participate. However, 75 of the 365 did not subsequently participate; they gave no clinical specimens and turned in no diaries, despite repeated contacts by the field staff. Attempts were made until August, 1977 to persuade the originally recruited families (n = 365) to participate. After that, the decision was made to concentrate field staff efforts on maintaining the 290 participating families and to drop the disproportionate effort of attempting to reach the 75 non-participants. Therefore, only the 290 participating families are included in the Health Watch data analysis (TABLE 3).

TABLE 3. SUMMARY OF HEALTH WATCH RECRUITMENT AND PARTICIPATION[a]: APRIL 3 - AUGUST, 1977

Sampling zone	Families recruited April, 1977		Families actually participating August, 1977	
	No.	%	No.	%
Zone 1	125	34.3	95	32.7
Zone 2	118	32.3	93	32.1
Zone 3	122	33.4	102	35.2
Total	365	100.0	290	100.0

[a] Based on diary participation.

Health Watch Diary--

Diary design--An easily maintained dairy was patterned after one designed by Dr. Seymour Sudman of Survey Research Laboratory. Each diary provided directions and space for self-reporting of any illnesses that occurred in a 2-week period. The information requested included:

- date illness began
- person in family experiencing illness
- nature of illness and/or symptoms
- number of days ill with no restriction of activity
- number of days of restricted activity
- medications taken
- physician consulted
- hospitalization
- date of recovery

Usually the diary was maintained by the health questionnaire respondent, i.e., the wife/mother of the household. Occasionally, older children would write in the details of their own illnesses.

Illness definition--Health Watch participants were instructed to record any and all symptoms, illnesses, and injuries regardless of apparent severity. This was done in hopes that over-reporting rather than under-reporting of illnesses would occur. When the diaries were reviewed by the central office staff, only relevant, selected illnesses were chosen for tabulation (TABLE 4). These were illnesses which could have a causal association with aerosols from the sewage treatment plant. Conditions or isolated symptoms such as sun poisoning, backache, constipation, headaches, drug and vaccine reactions, cramps, and fatigue were not coded for health data analysis.

Diary participation--TABLE 5 summarizes the number of families and persons entering and completing the Health Watch. The distributions of these families and persons in each zone were similar. More detailed comparisons of these subgroups will be presented in RESULTS.

TABLE 5. SUMMARY OF HEALTH WATCH PARTICIPATION AND COMPLETION:[a] APRIL 3 - NOVEMBER 26, 1977

Sampling zone	Number entering Health Watch		Number completing Health Watch			
	Families	Persons	Families		Persons	
			No.	%	No.	%
Zone 1	95	306	82	86.3	252	82.4
Zone 2	93	289	80	86.0	245	84.8
Zone 3	102	274	84	82.3	227	82.8
Total	290	869	246	84.8	724	83.3

[a] Based on diary participation.

TABLE 4. ILLNESSES SELECTED FOR ANALYSIS

- Respiratory
  - Upper respiratory infections
  - Bronchitis (infectious)
  - Pneumonia
  - Respiratory allergies
  - Asthma
  - Breathing difficulties specifically attributed to air pollution
  - Other respiratory symptoms

- Gastrointestinal
  - Nausea with or without headache
  - Gastroenteritis
  - Diarrhea with or without headache
  - Other GI symptoms

- Eye and ear
  - Conjunctivitis
  - Blepharitis
  - Otitis
  - Burning, itchy, watery eyes
  - Other eye and ear symptoms

- Skin
  - Allergic rashes, hives
  - Eczema
  - Boils
  - Abscesses
  - Other skin infections

- Other infections
  - Childhood infections
  - Genitourinary infections
  - Other acute infections

- Flare-up of chronic condition

- New chronic condition

It can be seen in TABLE 6 that 52 percent of the families which dropped out had done so by data-collection period 4, that is, 2 months into the study. Seventy-five percent of the attrition occurred in the first 2½ months of the study.

TABLE 7 summarizes the reasons given for dropping out of the Health Watch. The most frequent reason was moving out of the study area. In most of the cases, no reason was offered or could be elicited by the field staff.

TABLE 7. EXPLANATIONS FOR ATTRITION IN HEALTH WATCH

Reason given	Families	
	No.	%
None given	21	48.0
Moved from study area	11	25.0
Illness in family	3	7.0
Too much trouble	2	5.0
Non-cooperative children	2	5.0
Problem with field person	2	5.0
Language	1	2.0
Out of town during study period	1	2.0
Study created marital problems	1	2.0
Total	44	100.0

It can be seen in TABLE 8 that overall, 80 percent of the diaries were actually collected. Participation during the first 2 weeks was the lowest (33 percent) while families were still being recruited. The maximum participation was reached by May 1-14 (data-collection period 3) and declined only slightly thereafter.

Throat and Stool Specimen Collection--

Children 12 years of age and under were asked to provide biweekly throat and stool specimens. These specimens were considered important in order to identify agents associated with reported illness and to monitor for inapparent infections. Throat specimens alone could serve as sources of many respiratory and gastrointestinal bacterial and viral pathogens. However, pathogenic enteric virus usually can only be recovered from throat cultures for short periods of time (about 5 days) whereas they may be recovered for up to 6 weeks post-infection from stool specimens. In

TABLE 6. ATTRITION OF FAMILIES IN HEALTH WATCH BY DATA-COLLECTION PERIOD AND SAMPLING ZONE

Data-collection period, 1977		No. of families which dropped out[a]				Cum. %
No.	Date	Zone 1	Zone 2	Zone 3	Total	
1	April 3-16	0	0	0	0	00.0
2	April 17-30	2	3	2	7	16.0
3	May 1-14	3	0	4	7	32.0
4	May 15-28	1	6	2	9	52.0
5	May 29-June 11	4	2	0	6	66.0
6	June 12-25	1	0	3	4	75.0
7	June 26-July 9	0	0	1	1	77.0
8	July 10-23	1	0	0	1	80.0
9	July 24-Aug. 6	1	1	0	2	84.0
10	Aug. 7-20	0	0	1	1	86.0
11	Aug. 21-Sept. 3	0	1	1	2	91.0
12	Sept. 4-17	0	0	1	1	93.0
13	Sept. 18-Oct. 1	0	0	0	0	93.0
14	Oct. 2-15	0	0	2	2	98.0
15	Oct. 16-29	0	0	0	0	98.0
16	Oct. 30-Nov. 12	0	0	1	1	100.0
17	Nov. 13-26	0	0	0	0	100.0
	Total (%)	13 (29.5)	13 (29.5)	18 (41.0)	44	(100.0)

[a] Based on diary participation.

TABLE 8. NUMBER AND PERCENT OF EXPECTED DIARIES COLLECTED BY DATA-COLLECTION PERIOD

Data-collection period, 1977	Diaries collected	
	No.	%[a]
April 3-16	96	33.0
April 17-30	206	71.0
May 1-14	261	90.0
May 15-28	262	90.0
May 29 - June 11	257	89.0
June 12-25	251	87.0
June 26 - July 9	250	86.0
July 10-23	248	86.0
July 24 - August 6	248	86.0
August 7-20	248	86.0
August 21 - September 3	245	84.0
September 4-17	246	85.0
September 18 - October 1	242	83.0
October 2-15	241	83.0
October 16-29	231	80.0
October 30 - November 12	229	79.0
November 13-26	232	80.0
Total	3993	81.0
Mean	235	80.0

---

[a] Percent is based on the 290 families originally participating in the Health Watch.

addition, one adult in each of these families was asked to provide a biweekly stool specimen for the purpose of monitoring for apparent, inapparent, and intra-family spread of infections.

Throat swabs were collected by public health nurses who were familiar with but briefly retrained in this procedure by the project staff. Stool specimens were collected in large plastic tubs which could be suspended via plastic handles in the toilet bowl. These specimens were obtained earlier on the day of the nurse's visit and either refrigerated or placed in a cool area of the house until the nurse's arrival. Laboratory results were reported to the families on a quarterly basis. Specimens were also collected during acute illnesses of any family member. The submission of these "emergency" specimens depended on the family's initiative in contacting the central office. Laboratory results of the emergency specimens were telephoned to the family immediately and then confirmed in writing, as part of the quarterly report.

TABLE 9 summarizes the expected and actual numbers of persons giving specimens and the number of specimens received. Judging from the percentage of people who gave specimens, throat swabs were more acceptable (average = 9.4 specimens/person) to individuals than were stool specimens (average = 6.7 specimens/person). Even for throat cultures, the number of specimens received was much lower than expected due to attrition, late recruitment into the study, and non-cooperative children. The difficulty in obtaining specimens increased in September when the children returned to school. Their schedules were busy, and they often missed the appointment with the nurse.

Field Procedures--

Field staff recruitment--Just as interviewers were selected from the study area, attempts were initially made to hire local nurses for the field staff. The Skokie Health Department, the Visiting Nurses Association of the area, local nursing clubs, local schools of nursing, and hospitals as well as the Illinois Nursing Association were contacted, but no interested nurses were recruited through any of these channels. Oakton Community College, which had an LPN (Licensed Practical Nurse) training program, provided seven applicants, and although none had field experience, they were all hired, largely upon the recommendation of the LPN program director. Within 1 month, two of the LPNs had resigned (one for health reasons and one because she did not like the job); within 2 months, five more LPNs were terminated because they were not visiting their families regularly or at all.

Contact was made with SPH (School of Public Health) students in the MPH (Masters of Public Health) program. Seven were hired including three nurses. This constituted the basic field staff core. Several additional persons were hired from Augustana School of Nursing, Northwestern University, and North Park College, all of which are located near the study area.

A great deal of time was expended in recruiting field staff personnel. This could have been obviated by employing public health nurses (or nursing

TABLE 9. EXPECTED PARTICIPATION AND ACTUAL STATUS OF CLINICAL SPECIMENS BY TYPE OF SPECIMEN

Participant/specimen status	Type of specimen			
	Stool		Throat	
	No.	%	No.	%
No. people expected to give specimen[a]	180	100.0	111	100.0
No. people giving one or more specimens	80	44.0	81	73.0
No. specimens expected[b]	3,060	100.0	1,887	100.0
No. specimens received	541	17.7	757	40.1
Ave. no. specimens received/participant	6.7		9.4	
Reason specimen not received				
Dropped from program	334	10.9	209	11.1
Refused to submit	1,273	41.6	412	21.8
Family not contacted	908	29.7	496	26.3
Temporary absence from study area	4	0.1	13	0.7
Total number not received	2,519	82.3	1,130	59.9

[a] Based on the number of people who actually participated in some phase of the Health Watch and who agreed to provide specimens.

[b] No. of specimens expected = (no. of people expected to give specimen) x (17 data-collection periods).

students or public health students) under a contract for the duration of the project. As stated previously, this would have been costly in terms of wages, but would probably have resulted in less family attrition.

Field staff training--The project staff developed a manual for training the field staff. An all day training session was used to demonstrate procedures for collection of throat swabs, proper handling of stool specimens, review of diaries, and proper completion of various forms required in the project. As subsequent staff members were added, they were trained on an individual basis in the central office. Additionally, a new staff person would accompany a more experienced staff member on several family visits. Seeing the entire routine in action gave the new persons a feeling of confidence in dealing with their assigned families.

Home visits--Portions of the 290 Health Watch families were assigned to each field staff representative. If clinical specimens were to be collected, a nurse was assigned to the family. If only diaries were being collected, a public health student or other responsible student was utilized. Every family was to be visited every 2 weeks. During the visit, the diaries and/or specimens were collected, the diaries were reviewed on-the-spot for completeness and legibility, questions were answered, and the family was encouraged to continue in the study.

Clinical specimens were deposited at a central point in the study area and transported in ice each morning to the State Laboratory for immediate processing. Completed diaries were deposited at the same collection site and were picked up on a weekly basis by the central office project staff. New diaries were available for the field workers at the collection site, as well as supplies for the nurses to use in collecting clinical specimens.

Diary Verification--

During two data-collection periods, a 10.0 percent random sample of diaries was verified over the telephone by the central office staff. The sample was drawn so that 10.0 percent of each field worker's cases were verified each time and so that different families were telephoned each time.

In all, 55 families were selected for diary verification. Forty-eight diaries were completely correct; one diary had correct health information but one incorrect reporting of "number of days present during the data collection period"; and six families could not be contacted for verification.

Seroepidemiological Survey--

All persons 6 years of age and older (n = 837) were requested to give two blood samples, pre- and post-study. The sera of each paired-blood were tested in the Virus Serology Laboratory in the Division of Laboratories, Illinois Department of Public Health, for antibodies to 12 viral agents (APPENDIX A). These included Polioviruses, Types 1-3; Coxsackieviruses B1-B5, and Echoviruses 3,6,9, and 12 which: (1) are known to commonly populate sewage; (2) are stable and could be emitted into sewage aerosols;

and (3) are known to be common pathogens for man which may cause either clinical or subclinical illness. Enteric viruses have been associated with gastrointestinal, respiratory, cutaneous and/or combined illness.

Most pre-study blood samples (73.8 percent) were obtained during one all-day session conducted at the Skokie Health Department. Three rounds of home visits were arranged to obtain blood from elderly, ill, and working persons. Medical technicians and senior-year medical technology students were hired to draw blood at the various sessions. Whenever possible, a field staff worker was present at the all-day session and accompanied the technician on home visits.

One all-day session and two rounds of home visits were used to obtain the second blood samples. In addition, a new method, that of subcontracting with a private medical laboratory (Mason-Barron Laboratories, Skokie, Ill. 60076) in the study area was employed to draw blood from study volunteers. While only 11 percent of the second samples was obtained in this manner, this represented persons who were willing to give blood but whose work schedules prohibited either their coming to the all-day sessions or their being home for a personal visit. Therefore, this use of the private laboratory was deemed very beneficial to the outcome of the project. A final summary of blood-collection results may be found in TABLE 10.

TABLE 10. OVERALL SUMMARY OF BLOOD-COLLECTION RESULTS

Status	Number of persons [a]		
	First sample	Second sample	Paired sera
Blood collections made	424	327	318
Refusals, dropouts, etc.	413	510	---
Total	837	837	318

[a] Includes only Health Watch participants 6 years of age and older.

Paired sera were analysed for both the spectrum of antibodies present and for rises in antibody titers, as evidence of infection during the observation period. Single blood samples were similarly tested but were not included in antibody prevalence or incidence data analysis. Serology results were mailed to the blood donors in May, 1978, upon completion of serological analysis.

Data Reduction and Processing--

All diaries were reviewed for completeness and clarity in the central office. Families were telephoned by the central office to clarify diary entries or obtain additional information for coding. All diary information was numerically coded for computer input by Survey Research Laboratory. The diary and clinical data along with the questionnaire data were stored in a personal health file which was referenced according to an individual and household identification number. Statistical Analysis System (SAS) format was utilized for retrieval and analysis of both Health Watch diary data and clinical data.

Methodology for Environmental Monitoring Program

General Description--

The environmental monitoring program was designed to characterize the nature and degree of exposure of the study population to pollutants emitted during sewage treatment. Three types of materials were monitored in air and sewage: viable particles, non-viable particles, and gases. Measurements were made over an 8-month period at the sewage treatment plant and in the surrounding community.

The viable monitoring protocol for air included sampling for total aerobic bacteria-, total and fecal coliform-, coliphage-, and animal virus-containing particles. Each time an air sample was taken, an aeration tank grab sample was taken for analysis of corresponding organisms. The term "Total Viable Particles" is used in this report to refer to total aerobic bacteria-containing particles in the air. Concentrations of total viable particles were measured on a regular basis (approximately every other day) at the plant and in the community for 8 months (April-November, 1977). Concurrent monitoring of total aerobic bacteria in the aeration tank sewage was performed for comparison. Initial attempts to monitor for total and fecal coliform were made using an All-Glass-Impinger on 6 days during April and May. These samplers were found to be below the sensitivity required for detection of the concentrations present. Beginning in September airborne total coliform samples were taken with Andersen samplers on days of total viable particle sampling and with a Litton large volume air sampler (LVAS) 1 day per week. The sewage samples collected for total aerobic bacteria determinations were also assayed for total and fecal coliforms. Airborne coliphage measurements were originally scheduled to be taken once every other week. However, many equipment problems were encountered with the LVAS, and only eight coliphage in air and 24 coliphage in sewage measurements were obtained. Animal virus in air samples were obtained for 2 days (one upwind and one downwind each day). Twenty-three sewage samples were taken for animal virus determinations.

Monitoring of non-viable constituents was conducted every 5 days from April through November on the plant and in the community. Sewage samples were collected for determinations of metals, nitrates, and sulfates on each day that air samples were taken for these non-viable constituents. Sewage samples were also collected for physico-chemical characteristics. Air sampling was performed for total suspended particulates (TSP) and gases. The materials for which quantitative determinations were made included vanadium (V), chromium (Cr), manganese (Mn), nickel (Ni), copper (Cu), arsenic (As), selenium (Se), cadmium (Cd), tin (Sn), mercury (Hg), lead (Pb), antimony (Sb), sulfates ($SO_4^=$), and nitrates (NO_3^-). The gases collected were chlorine, nitrogen dioxide, hydrogen sulfide, ammonia, and sulfur dioxide. Five-day BOD, COD, total filterable solids, total suspended solids, ammonia nitrogen (NH_3-N), nitrate and nitrite nitrogen (NO_3-NO_2-N), total phosphorus, and pH were determined for each physico-chemical sewage sample.

A meteorological station was installed on the plant site for continuous monitoring of wind direction, wind speed, temperature, relative humidity, ultraviolet radiation, total radiation, and rainfall. This equipment provided integrated wind direction data for use in the selection of the monitoring sites.

The environmental monitoring data were used to develop a "personal exposure index" for the residents of the study area. This was accomplished by using maps of concentration isopleths generated from the air pollution data. The "personal exposure index" takes into account meteorological factors as well as the actual measured pollution levels.

Selection of Monitoring Sites--

The selection of sites for viable particle sampling was based on the need to characterize the exposure with regard to wind direction. Three sites in a line at various distances downwind from the aeration tanks and one upwind were chosen for this purpose. Based on dispersion distances observed in previous studies of airborne organism distributions and the geographic distribution of residences in the study area, 16 community sampling sites were selected in two concentric circles of 0.8-km and 1.6-km radii from the plant, and four on-plant sites were chosen along the north, east, south, and west edges of the aeration tank batteries. In order to select the four sites for a given sample-collection period according to wind direction, the 20 possible viable sampling sites were chosen to closely follow the eight major wind direction patterns (N↔S, E↔W, NW↔SE, and SW↔NE). At each sampling site, a location for the mobile monitoring unit was chosen away from all tall buildings or other obstructions. For on-plant site selection, wind direction was categorized into one of four 90° sectors: NE to SE, SE to SW, SW to NW, and NW to NE.

The monitoring sites selected for the non-viable air measurements were based on different criteria than for the viable protocol. Each site was a permanent facility. The site at the plant was located near the aeration tanks. Two community sites were selected in high-density residential areas 1.6 km from the aeration tanks. Two other sites were located northeast of the plant approximately 0.8 and 1.6 km from the tanks. These selections were based on 1975 prevailing wind data for the north suburban area. The non-viable monitoring sites required access to a 110 volt electrical supply. It was also necessary to locate the equipment on a relatively flat roof not easily accessible to vandals and far from building exhaust systems.

Grab samples were collected at the inlet manifold of one of the aeration tank batteries in order to determine the concentrations of the pollutants which might be aerosolized. At this point, preliminary treatment effluent has been thoroughly mixed with return sludge. Although sampling from a midpoint in the aeration tank might have been more representative, this was considered too dangerous for field personnel to routinely perform. Samples for physical and chemical parameters were also taken at the final outfall of the plant in order to compare our analysis techniques with those of the Sanitary District laboratory.

Description of Monitoring Sites--

TABLE 11 lists the monitoring sites by designation and location description for the sampling of airborne viable particles. The on-plant sites (sites 1-4) are illustrated in Figure 2, and the community sites (sites 5-20) are depicted in Figure 4. The four on-plant sites (Figure 2) are located adjacent to the aeration tanks along the centers of the north, east, south, and west edges of the batteries. It can be seen in Figure 4 that eight of the community sites (5-12) are situated on the 0.8-km radius (from plant) circle, and the remaining eight community sites (13-20) are on the 1.6-km radius circle. A detailed description of the environmental conditions at each site is given in APPENDIX B. The area as a whole can be characterized as residential with some light industry and commercial offices directly south and east of the plant (Figure 4). The North Shore Channel runs north and south approximately 0.8 km east of the plant. Excavation for the Metropolitan Sanitary District's (MSD) Tunnel and Reservoir Plan project was being carried out across the street from the MSD's field services office at 3200 Oakton (sites 6 and C).

The Andersen samplers, used to make the total viable particle and total coliform in air measurements, were situated on top of a mobile monitoring unit at the height of about 1.8 meters (6 feet) above ground during sampling. Power was supplied from lead-acid batteries.

TABLE 12 lists the sites of the stationary installations for the sampling of airborne non-viable constituents (total particulates, gases, metals, nitrates, and sulfates). Site A consists of two adjacent sites (A1,A2) northeast of aeration tank C (Figure 2). Sites B and E are in a high density residential area, and sites C and D (Figure 4) are downwind of what was preliminarily determined to be the prevailing winds at the plant. Each of these non-viable monitoring stations contained a high volume air sampler (for total suspended particulate, metals, sulfate, and nitrate measurements) and a bubbler sampler for simultaneous collection of five gases. The installation dates and heights for this equipment are given in TABLE 12. On August 22, a five-stage Andersen Head (for total particulate, sulfate, and nitrate measurements) was added to one of the two Hi Vols at plant site A.

Sewage samples for determination of total aerobic bacteria, total coliform, fecal coliform, coliphage, and animal virus concentrations were taken from the inlet to aeration tank battery B. This sampling point is depicted in Figure 2. Additional samples for animal virus were taken at the outlet of battery B in an attempt to characterize changes in viral concentration in the aeration tanks.

Monitoring and Analyses of Environmental Samples--

Total viable particles in air--Sample collection for determination of total viable particle concentrations began on April 18, 1977. Several trial

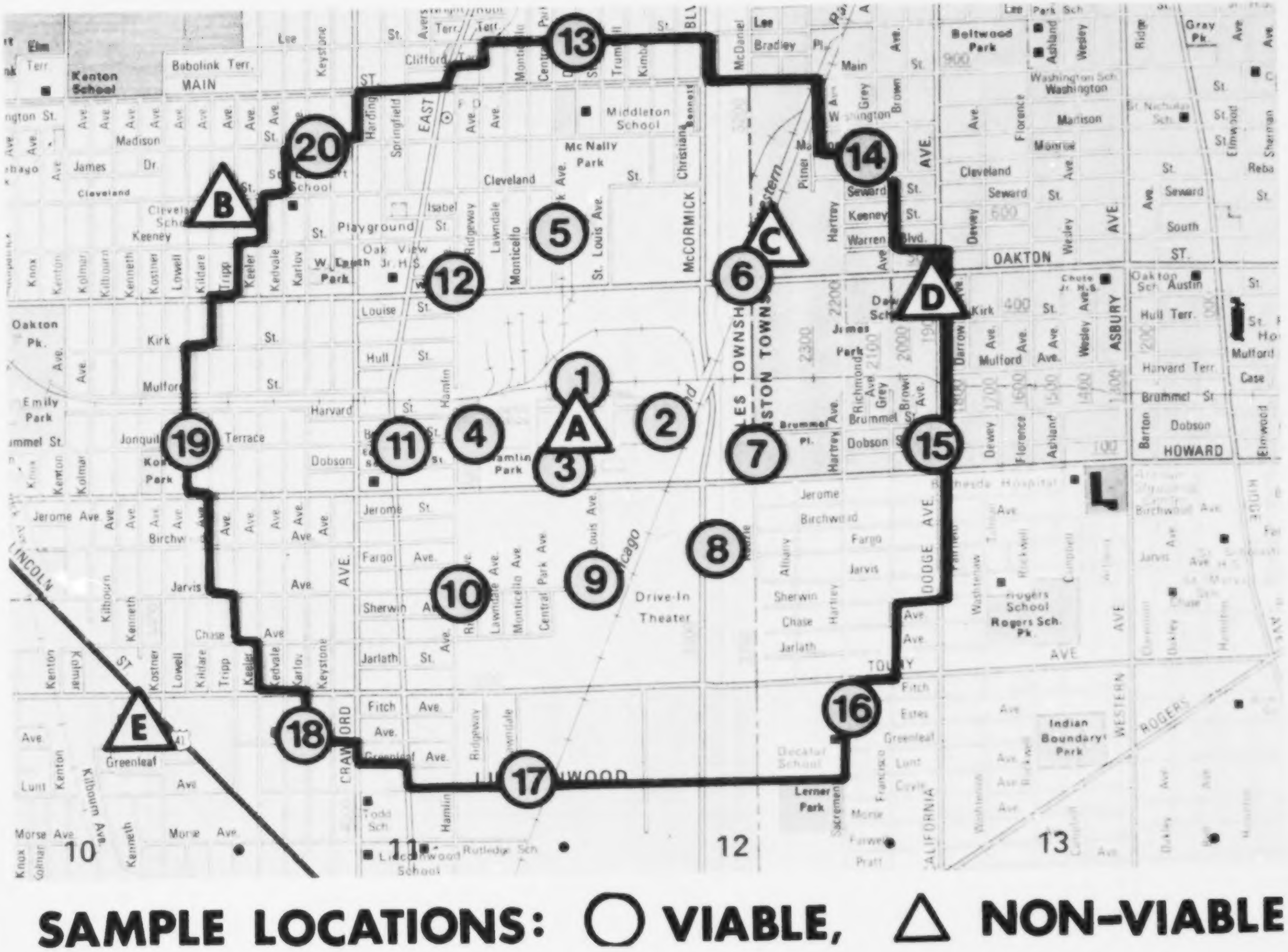


Figure 4. Map of community sampling sites.

TABLE 11. LIST OF MONITORING SITES FOR SAMPLING OF AIRBORNE VIABLE PARTICLES

Site no.	Sampling site location[a]
1	Northwest corner of aeration tank battery B
2	Center of east edge of aeration tank battery A
3	Southeast corner of aeration tank battery C
4	Center of west edge of aeration tank battery D
5	Northeast corner of Central Park and Keeney on Keeney
6	Parking lot of MSD office (3220 Oakton)
7	West edge of Bell and Howell parking lot on Howard
8	East side of McCormick Blvd. across from FEL-PRO Corp. (about 7450 north)
9	Southwest corner of Jarvis and St. Louis on Jarvis
10	Northeast corner of Jarvis and Hamlin on Jarvis
11	Northeast corner of Brummel and East Prairie on Brummel
12	Northeast corner of Oakton and Hamlin on Hamlin
13	South of Drake and Lee on Drake
14	Northeast corner of Cleveland and Hartrey on Cleveland
15	West of Dobson and Dodge on Dobson
16	Southeast corner of Sacramento and Fitch on Fitch
17	East of Lawndale on Lunt
18	Northeast corner of Karlov and Estes on Estes
19	Northeast corner of Lowell and Brummel on Brummel
20	Southwest corner of Madison and Karlov on Karlov

[a] A mobile monitoring facility was used at these sites. Samplers were at height of 1.8 meters above ground during sampling. A detailed description of each site appears in Appendix B.

TABLE 12. LIST OF MONITORING SITES FOR SAMPLING OF NON-VIABLE AIR CONSTITUENTS

Site designation	Sampling site location	Installation dates		Height above ground of sampling installation, meters
		Hi Vols	Bubblers	
A	Northeast of aeration tank C	4/1/77 & 5/11/77	5/11/77	1.1
B	Roof of Cleveland School, Cleveland and Kildare	4/1/77	5/11/77	8.5
C	Roof of MSD Office, 3200 Oakton	5/23/77	5/23/77	7.9
D	Roof of Dawes School, Oakton and Dodge	5/23/77	5/23/77	3.3
E	Roof of Lincolnwood Village Hall, Lincoln and Fitch	5/23/77	5/26/77	4.3

field runs were made prior to April 18. Sampling days were restricted to Sunday through Thursday due to laboratory arrangements. Hence an every-other-day sampling schedule for the duration of the project data-collection period resulted in a repeated pattern of 3 days of sampling one week followed by 2 days the next week. An attempt was made to alternate day and night samplings. Each day or night a total viable particle sample was scheduled, four sampling runs were made; one upwind of the aeration tanks and three downwind. These four sites were identified by determining the resultant wind direction for the previous 1-hour period from the on-plant meteorology station. Three monitoring sites (one on the plant, one on the 0.8-km radius from the tanks, and one on the 1.6-km radius circle) falling on a line downwind from the plant were then selected. An upwind site on the 0.8-km radius circle was chosen as a control site. Due to vehicle and personnel limitations the four sites selected for a particular sampling day had to be monitored consecutively. The sampling site order was determined randomly. A summary of the number of total viable particle samples collected through November, 1977 is included in TABLE 13.

Andersen 2000 six-stage (A6S) Viable Samplers were used to collect total viable particles. This multi-orifice cascade impactor consists of six aluminum stages accompanied by six glass petri dishes and a pump. Each stage collects particles of pre-determined size range with stage 6 collecting particles of 0.65 to 1.1 μm diameter and stage 1 collecting particles of 7.7 μm and above. BBL trypticase soy agar (TSA) was used as the collection medium. As of June 23, a fungal inhibitor, Actidione (Upjohn), was added to the plates to control interfering fungus growth. The agar-Actidione plates and samplers were prepared by the Illinois Institute of Technology Research Institute (IITRI). Before routine use of a fungal inhibiting additive was begun, IITRI performed an evaluation of the effect of their addition on total aerobic bacteria growth (APPENDIX C).

The Andersen samplers loaded with prepared dishes were refrigerated until sample collection time. Eight samplers were available for the environmental monitoring program. The samplers were calibrated at a flow rate of 28.3 l/min (1 cfm) using a wet-test meter. These calibrations were verified three times during the study and were found not to change significantly.

Each sampling run was made with the sampler situated on top of the mobile monitoring vehicle (sampler at a height of approximately 1.8 meters above ground). The vehicle contained a battery and charger system which supplied power for the continuous duty 28.3 l/min airflow pump. The vehicle was not running during each test. No sampling was done during periods of precipitation. The sampling runs were performed by University of Illinois project personnel. Fifteen-minute samples were collected. All data-collection information was recorded on the appropriate form. At the end of each run the petri dishes were removed from the sampler, labelled, and incubated at 35°C for 48 ± 5 hours in the on-plant laboratory facility.

Constituent	Method of sample collection	Date of first sample	No. of samples collected		
			Day	Night	Total
Total aerobic bacteria-containing particles in air (total viable particles)	Andersen six-stage viable air sampler	4/18/77	32[a]	40[a]	72[a]
Total aerobic bacteria in sewage	grab samples[b]	4/18/77	42	39	81
Total coliform in air	Andersen	9/13/77	11[a]	15[a]	26[a]
	LVAS	8/24/77	9[c]	0[c]	9[c]
Fecal coliform in air	LVAS	8/24/77	9[c]	0[c]	9[c]
Total coliform in sewage	grab[b]	4/14/77	46	40	86
Fecal coliform in sewage	grab[b]	4/14/77	45	40	85
Coliphage in air	LVAS	5/03/77	4[d]	0[d]	4[d]
Animal virus in air	LVAS	9/29/77	2[d]	0[d]	2[d]
Coliphage in sewage	grab[b,e]	5/03/77	24	0	24
Animal virus in sewage	grab[b,f]	5/16/77	23	0	23

[a] These numbers represent the number of sample-collection periods. Each day or night sample-collection period involved one upwind and three different downwind sampling runs.

[b] Sewage samples were taken from inlet to aeration tank battery B.

[c] These numbers represent the number of sample-collection periods. The following samples were collected: in one period, one upwind and one downwind; in two periods, one upwind and two downwind; in six periods, one upwind and three downwind.

[d] These numbers represent the number of sample-collection periods. In each period, one upwind and one downwind sample were collected.

[e] Five samples are pooled samples of aeration tank influent and effluent, one is influent only, and nine are pairs of influent and effluent samples collected on the same day.

[f] Three samples are pooled samples of aeration tank influent and effluent, four are influent only, and eight are pairs of influent and effluent samples collected on the same day.

Analyses for concentration of total viable particles in the air were performed at the laboratory facility on the plant grounds. After incubation, the number of colonies per plate was counted (Quebec colony counter) and recorded by project personnel. The concentrations for each stage were determined by applying the positive hole count correction factor. The most probable number of bacteria-containing particles were obtained from tables based on statistical considerations of the number of positive holes (among the 400 orifices per stage) for stages 3 to 6 determined by Andersen (88). A quality control evaluation of the persons counting the organisms was made and a statistical measure of counting precision was developed (APPENDIX D).

Total and fecal coliform in air--Sample collection for airborne total coliform measurements using the Andersen sampler began September 13. The sample-collection schedule for total coliform was identical to that for total viable particle monitoring. TABLE 13 summarizes the sample collection for total coliform through November, 1977. The same Andersen samplers described for total viable particle monitoring were used for total coliform measurements. M-Endo broth (Difco) containing 1.5% Bacto-Agar (Difco) with the fungal inhibitor, Actidione, was used as the collection medium. All plates and samplers were prepared by IITRI.

The sampling runs were performed as described for total viable particle measurements with the following changes. A 30-minute sampling time was used for total coliform runs. At the end of each run, the petri dishes were incubated at 35°C for 24 ± 2 hours in the plant laboratory. Immediately following this incubation, the plates were transported to IITRI. Upon receipt of the plates, IITRI counted the total coliform colonies under fluorescent light with a binocular microscope and determined the total coliform concentrations using the positive hole correction factor (88). For a more detailed description of sampler preparation and quality control methods, see APPENDIX C.

In addition to using Andersens for total coliform sample collection, a Litton large volume air sampler (LVAS) was used for total and fecal coliform sampling beginning in August. Due to the complexity of operation, this sampler was used approximately one day a week from August to November (TABLE 13). The same protocol for site selection and mobile sampling unit operation were used. Sampling was done at approximately 1.2 meters (4 feet) from the ground and upwind of the sampling vehicle.

The LVAS sampler passes a stream of air through a corona discharge zone to charge any particles within the air column. The particles then pass through an electrostatic field which precipitates them into a film of liquid flowing over a rotating disc. This liquid is then collected for assay.

All sampling was performed by project personnel. The equipment and media were prepared by IITRI. A field decontamination method employing live steam and ultraviolet light was devised by IITRI, and decontamination was performed at each sampling site. For details of the decontamination procedure and sampling, see APPENDIX C. The fluid flow rate was between 6 to 10 ml/min, electrostatic precipitator voltage ranged from 10 to 15 kilovolts, and airflow was 1.0 m^3/min. Phosphate-buffered water with 0.01 percent phenol red and 25 percent BBL trypticase soy broth (TSB) was used as the collection medium. One hundred milliliters of fluid were collected as a control, and two 15-minute samples were taken, one for total coliform and one for fecal coliform, at each site.

The fluid was collected directly into a Millipore membrane filtration apparatus containing a 0.45 µm pore-size 47 mm diameter membrane filter. All samples were filtered and assayed by project personnel at the plant laboratory immediately after field sampling. Tubed m-Endo and m-FC media (Difco) were used for total and fecal coliform assays, respectively (89). The plates were incubated at 35°C for 24 ± 2 hours. They were then refrigerated and/or transported on ice to IITRI for counting as described above.

Coliphage and animal-virus-containing particles in air--Sampling for animal virus was conducted on 2 days, September 29 and October 27. One upwind control and one downwind sample (as defined above) were collected on the plant grounds on each day. All sampler preparation, sampling, filtration, and assays were done by IITRI personnel by methods described by Fannin et al. (56). For a description of these procedures, see APPENDIX C.

The LVAS was also used for airborne coliphage collection on 4 days: May 3, May 16, June 13, and July 25. One upwind and one downwind sample were collected on the plant grounds on each day. On-site sample collection was performed by project personnel. All other aspects of the procedure were performed by IITRI according to Fannin et al. (56). For a description of these procedures, see APPENDIX C.

Due to equipment and decontamination problems it was decided that use of the one available LVAS for both coliphage and total and fecal coliform sampling would not be feasible. As a result, sampling for coliphage was cancelled after July 25.

Total aerobic bacteria, total and fecal coliform, animal virus and coliphage in sewage--A sewage sample for determination of total aerobic bacteria and total and fecal coliform concentrations was collected each day that total viable particles and total coliform were sampled in air. Although difficulty with air monitoring equipment for coliphage prevented collection of the originally anticipated number of air samples, sewage samples for coliphage were collected approximately every 2 weeks from May 3 to September 29 and every week from September 29 to November 17. Sewage samples for animal virus were collected beginning May 16 and followed the coliphage sampling schedule after that. The sewage samples were taken from the inlet to aeration tank battery B. See TABLE 13 for a summary of the sewage samples collected.

Each sewage sample was collected by dipping a polyurethane container directly into the tank. The samples for animal virus were collected in clean glass 5-liter bottles. The container was then capped, labelled, and stored on ice overnight. The sample was delivered to IITRI the following morning in an ice chest.

Analysis of sewage samples for total aerobic bacteria concentrations was performed by IITRI. The standard method (Standard Plate Count) (89) was not used since it requires plating of samples in liquid medium rather than on an agar surface. Standard Plate Count levels in sewage would not be comparable to counts from aerosols taken with Andersen samplers, which impact particles on an agar surface. Total aerobic bacteria on trypticase soy agar (TSA) was determined by the spread plate procedure. Appropriate dilutions of each sewage sample were plated in duplicate on TSA plates. The plates were subsequently incubated for 48 ± 2 hours at 35°C and counted using a Quebec colony counter.

Total coliform bacteria concentrations were determined by IITRI using the standard membrane filter procedure as described in Standard Methods (89). Appropriate sewage dilutions were filtered in duplicate through 0.45 µm Millipore membrane filters (or equivalent). The filters were placed on adsorbent pads in plastic petri dishes containing m-Endo medium, incubated at 35°C for 24 ± 2 hours, and counted under fluorescent light using a binocular dissecting microscope.

Fecal coliform bacteria concentrations were determined by IITRI using the standard membrane filter technique as described in Standard Methods (89). The procedure described for total coliform in sewage was followed with the following exceptions:

1) m-FC medium was used
2) The plates were placed in water-tight containers and incubated in a waterbath at 44.5°C for 24 ± 2 hours.

Analysis of sewage samples was performed by IITRI for animal virus and coliphage. For the first six animal virus samples, the Freon 113 processing - direct inoculation procedure was used. Increased sensitivity for animal virus detection was found to be necessary, and the remaining samples were concentrated using an aluminum hydroxide - continuous flow centrifugation technique. Both procedures were used for coliphage analyses. For a description of these procedures, see APPENDIX C.

Total suspended particulates (TSP), metals, nitrates, and sulfates in air--Hi Vol measurements for TSP, nitrates, sulfates, and metals began May 19, 1977. Measurements were usually made every fifth day. Six RAC Hi Volume air samplers located at five different sites (TABLE 12) were run simultaneously on each scheduled sampling day. Due to background metal contamination of the glass-fiber filters employed for TSP measurements, analysis of these filters for ambient metal concentrations could not be performed. Whatman 541 filters were judged as an acceptable substitute for the glass-fiber filters for metals determinations. From June 28 on, three of the six Hi Vols were run with Whatman 541 filters for metals analysis, and three were run with glass-fiber filters for TSP, nitrate, and sulfate determinations. The sampling schedule was staggered with sites A, B, and F monitored for metals one day while TSP, $SO_4^=$, and NO_3^- were measured at sites A, C, and D. The next sampling day the procedures were reversed. This pattern was repeated throughout the project data-collection period. Beginning on August 22, the Hi Vol at site A2 was equipped with an Andersen Head to collect size-differentiated particulate samples. The sample-collection schedule for TSP, metals, nitrate, and sulfate measurements appears in TABLE 14.

Operation of the Hi Vols, conditioning, and weighing of the filters were carried out in accordance with the EPA reference method (90). Calibration of the samplers using a Bendix Variable Orifice Calibration Assembly was carried out periodically during the study period. Each sampling run lasted 24 hours (midnight to midnight). After the final filter weights were recorded, the filters were delivered to the appropriate laboratory. The Whatman filters were sent to Columbia Scientific Industries (CSI) for metals analysis. Minimum detectable limits for these analyses are presented in TABLE 15. The glass-fiber filters were delivered to the Cook County Environmental Control Laboratory for nitrate and sulfate determinations.

TABLE 15. MINIMUM DETECTABLE LIMITS FOR METALS

Element	Detection limit ($\mu g/cm^2$)	Detection limit ($\mu g/m^3$)[a]
V	0.01	0.002
Cr	0.10	0.022
Mn	0.10	0.022
Ni	0.04	0.009
Cu	0.04	0.009
As	0.05	0.011
Se	0.03	0.007
Cd	0.04	0.009
Sn	0.05	0.011
Sb	0.05	0.011
Hg	0.04	0.009
Pb	0.08	0.018

[a] Assumes average total volume of air = 1835 m^3. Average filter area = 413.67 cm^2.

TABLE 14. SUMMARY OF SAMPLE COLLECTION FOR NON-VIABLE CONSTITUENTS OF AIR AND SEWAGE FOR DATA-COLLECTION PERIOD APRIL-NOVEMBER 30, 1977

Constituent	Sampler	Date of first sample	No. of samples collected[a]					
			Site A	Site B	Site C	Site D	Site E	Total
Total suspended particulates (TSP)	Hi-Vol	5/19	45	30	22	23	20	140[e]
Metals in air (V, Cr, Mn, Cu, As, Se, Cd, Sn, Sb, Ni, Hg, Pb)	Hi-Vol (Whatman filter)	6/28	32	13	15	16	16	92[b]
Nitrates and sulfates in air	Hi-Vol	5/09	40	27	21	21	18	127[c]
Gases								
NO_2	Bubbler	5/19	35	16	16	16	18	101
H_2S	"	5/24	25	11	12	11	12	71
SO_2	"	5/19	36	17	17	16	16	102
Cl_2	"	8/12	31	14	14	13	14	86
NH_3	"	9/11	13	5	7	7	7	39
Physico-chemical tests in sewage	Grab	6/08	--	--	--	--	--	26 (13 inlet, 13 outfall)[d]

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[a] See TABLE 12 for key to sites.

[b] Each sample analyzed for all twelve metals.

[c] Each sample analyzed for sulfates and nitrates.

[d] Each sample analyzed for BOD_5, COD, total suspended solids, total filterable solids, total phosphorus, nitrate plus nitrite as nitrogen, ammonia nitrogen, and pH.

[e] All TSP concentrations collected on glass-fiber filters only.

The total suspended particulate concentrations were determined from the glass-fiber filters by project personnel according to the EPA reference method (90). The analytical methods used for the determination of 12 metals, nitrates, and sulfates are presented in TABLE 16.

Gases--Sampling for gas concentrations was done concurrently with the Hi Vol sampling. The two groups of sites (A-B-E and A-C-D, TABLE 12) were sampled alternately between sampling days. It was originally intended to collect equal numbers of samples of chlorine, nitrogen dioxide, hydrogen sulfide, sulfur dioxide, and ammonia. Trial runs for these gases indicated that methods for chlorine and ammonia required modification as the environmental concentrations were below detectable limits. As a result, reliable chlorine measurements did not begin until August 17. Ammonia measurements began on September 21. The sample collection for gases is summarized in TABLE 14.

Modified RAC five-gas bubbler trains were used to collect gases. The trains were modified as described below in order to achieve a satisfactory minimum detectable limit for NH_3 and also to provide a backup impinger for SO_2.

The bubbler samplers were located near the Hi Vol samplers. Each bubbler was equipped with a manifold to permit simultaneous sampling for a maximum of five gases. A membrane filter was used to remove particulate matter from the air prior to entry into the inlet. A second membrane filter was used to prevent the pump critical orifice from being plugged. Polytechnic, Inc. charged the bubbler tubes (polypropylene) with the appropriate absorbing reagents (TABLE 16) and then purged the systems with nitrogen in order to preserve the collection fluids.

The SO_2, NO_2, Cl_2, and H_2S bubblers were operated at approximately 200 ml of air/min for 24 hours per sampling run, the NH_3 bubbler at 5 l/min. In addition to the standard impinger supplied with the RAC five-gas sampler, a large fritted impinger was placed in the sampler's shelter for the collection of ammonia. This impinger, which ran off the pump used for the SO_2, NO_2, Cl_2, and H_2S measurements, was calibrated to operate at 5 l/min. The higher flow rate was needed to obtain a satisfactory minimum detectable limit. A careful analysis of the modified sampler train was conducted to make sure that the addition of the ammonia collection impinger did not interfere with the pump's ability to bring the impinger orifice for SO_2, NO_2, Cl_2, and H_2S to critical flow. The concentration of H_2S was never above the minimum detection limit from May 24 to October 1. Because of this, it was decided to cancel sampling for H_2S and use the extra bubbler tube as a backup trap for SO_2. The critical flow orifice was replaced and the flow rate calibrated every third run.

The samplers were delivered to nearby Polytechnic, Inc. for analysis. The methods used by Polytechnic for the gas concentration determinations are presented in TABLE 16. Polytechnic developed calibration curves and determined minimum detectable limits (TABLE 17). A quality control standard

TABLE 16. ANALYTICAL METHODS FOR AIR SAMPLE ANALYSES: NON-VIABLE CONSTITUENTS

Analyte	Performing laboratory	Method	Ref.[d]
Chromium	CSI[a]	Collection on Whatman 541 filter paper. Energy dispersive X-ray fluorescence spectrometry	1
Vanadium	CSI	" " "	1
Lead	CSI	" " "	1
Manganese	CSI	" " "	1
Nickel	CSI	" " "	1
Copper	CSI	" " "	1
Cadmium	CSI	" " "	1
Selenium	CSI	" " "	1
Tin	CSI	" " "	1
Antimony	CSI	" " "	1
Arsenic	CSI	" " "	1
Mercury	CSI	" " "	1
Nitrates	CCL[b]	Automated, copper-cadmium reduction method	2
Sulfates	CCL	Tentative method for determination of SO_4 in the atmosphere. Automated Technicon II. Methylthymol Blue procedure	3
Chlorine	P[c]	Methyl Orange-spectrophotometric determination	4
SO_2	P	Pararosaniline-TCM absorption	5
NO_2	P	Sulfanilamide-spectrophotometric determination	6
Ammonia	P	Absorption in sulfuric acid and spectrophotometric determination	7
H_2S	P	Absorption in cadmium hydroxide and spectrophotometric determination	8

(continued)

TABLE 16 (continued)

[a] Columbia Scientific Industries.
[b] Cook County Environmental Control Laboratory.
[c] Polytechnic Inc.
[d] References:

1. Rhodes, J.R.: Energy-Dispersive X-Ray Spectrometry for Multielement Pollution Analysis. IEEE Transactions on Nuclear Science 21(1): 608-617, 1974.
2. Federal Water Pollution Control Administration Methods for Chemical Analysis of Water and Wastes. November, 1969.
3. Environmental Protection Agency. Quality Assurance Branch. Environmental Monitoring and Surveillance Lab. National Environmental Research Center, Research Triangle Park, N.C. July 15, 1977.
4. Medycyna Pracy XXV. 1974. pp. 53-58. "A Determination of Cl_2 in the Air Using Kettner's Method." Department of Industrial Toxicology, Lodz.
5. Federal Register, Vol. 36, #84, pp. 113-115, 1971.
6. Federal Register, Vol. 38, #110, pp. 15, 75-76, 1973.
7. Standard Methods, 14th ed., pp. 412-415; Stern, Vol. 2, 2nd ed., pp. 104-105.
8. Methods of Air Sampling and Analysis, Intersociety Committee Method 701, pp. 426-432.

was run every second analysis for chlorine, nitrogen dioxide, and hydrogen sulfide, and every analysis for sulfur dioxide. The calibration curves for ammonia were verified periodically throughout the 3 months of ammonia sampling.

TABLE 17. MINIMUM DETECTABLE LIMITS FOR GASES

Gas	Detection limit (μg/sample, based on minimum absorbance)	Average total volume of air (m^3)	Minimum concentration	
			($\mu g/m^3$)	(ppm)
Cl_2	0.53	0.25	2.12	0.00074
NH_3	16	7.0	2.29	0.0032
NO_2	1.89	0.25	7.56	0.0040
H_2S	0.27	0.25	1.07	0.00076
SO_2	0.84	0.25	3.33	0.0013

Metals, nitrates, and sulfates in sewage--One-liter grab samples, one for metal and one for nitrate and sulfate analyses, were collected from the inlet to the B battery aeration tanks on each day air sampling for these parameters was done. Each sample was collected by dipping a polyurethane container directly into the tank. The samples were immediately frozen solid. When three samples for metal analyses had accumulated, they were packed in dry ice and sent to CSI, Inc., Austin, Texas, by 24-hour messenger service. The samples always arrived frozen. The sample for nitrate and sulfate was delivered on ice to the Cook County Department of Environmental Control in Maywood, Illinois.

At CSI, the following procedure was used to prepare samples for X-ray fluorescence analysis (personal communication: Dr. John Schindler, CSI, Austin, Texas):

> Ten ml of 6 N HNO_3 were added to the frozen sample. After complete melting, the whole sample was filtered through Whatman 541 and 1.2 μm Millipore filters giving a completely clear filtrate. One hundred ml of filtrate were diluted to 500 ml and ammonium acetate buffer added to maintain the pH at 4.0 throughout the precipitation. Ten ml of a freshly prepared 2 percent ammonium pyrolidine dithiocarbamate (APDC) (correctly known as ammonium tetramethylene dithiocarbarbamate, ATMDTC) solution were added. After 30 minutes the precipitate was collected on a Millipore HAWP filter (0.45 μm), dried, and analyzed by X-ray fluorescence (91).

The samples for nitrates and sulfates were thawed, split, agitated, and analyzed with a Technicon Autoanalyzer. Five ml of chloroform were added to the sample for nitrate analysis as a preservative.

Physico-chemical characterization of sewage--Beginning June 8, sewage samples for determinations of physico-chemical characteristics were collected every other Wednesday. On each scheduled Wednesday, one sample was collected from the inlet to aeration tank battery B and a final outfall sample was taken from the Pump and Blower station. The number of samples collected is summarized in TABLE 14.

Polyurethane containers were used to collect these samples. Delivery of the containers in an ice chest was made to the Illinois Environmental Protection Agency (IEPA), Chicago, within 4 hours of collection, and they were processed the same day. The IEPA performed the physico-chemical analyses according to Standard Methods (TABLE 18).

Meteorology--

A meteorology data acquisition system was set up on the plant grounds. This consisted of an 11-meter tower with sensors for temperature, humidity, wind speed and direction, solar radiation, ultraviolet radiation, and precipitation; a Weathermeasure Corp. Model M733-M9 Data Center; and Model SC701 Signal Conditioning Console (Figure 5).

System functions were controlled by an Intel 8080 microprocessor. In addition to control functions, the microprocessor was also programmed to calculate and display 1-hour vector averages of wind speed and direction, compute averages of all parameters, and convert all sensor input to engineering units. Modules for each parameter sensor were connected to the Model SC701 chassis. In addition to providing data to the Model M733, each module provided voltage and current outputs to drive a strip chart recorder and an electronic switching system for high and low calibration. The Model M733 was also equipped with a real time clock, a magnetic tape interface, ninetrack-tape recorder, and a digital-to-analog convertor.

The probes, modules, and recorders were all supplied by Weathermeasure Corp. as follows:

1) TRS - 1/4 general purpose platinum resistance thermometer assembly; MD626 platinum temperature module, range - 30° to 110°F.
2) HM111 relative humidity sensor; MD 111 P/A humidity circuit module, range 0 to 100%.
3) W 101 - P - Ac/540 Skyvane wind sensor with an AC generator for wind speed and a 0° - 540° potentiometer for wind direction; MD 104-2 wind speed module, range 0 - 100 mph; MD 103-Z wind direction module, range 0° - 540°.
4) P511 - E heated rain and snow gauge, tipping bucket. MD432 event accumulator module.
5) Eppley Lab, Inc. ultraviolet radiometer No. 15596 with circuit, range 290-385 nm.
6) R413 Star pyranometer; MD104-4 solar radiation module, range 0-2 gm cal/cm^2 rain.
7) REW - 2P-12V/12V potentiometric recorder for wind speed and direction.
8) REW - 12V-6 potentiometric recorder for all other parameters.

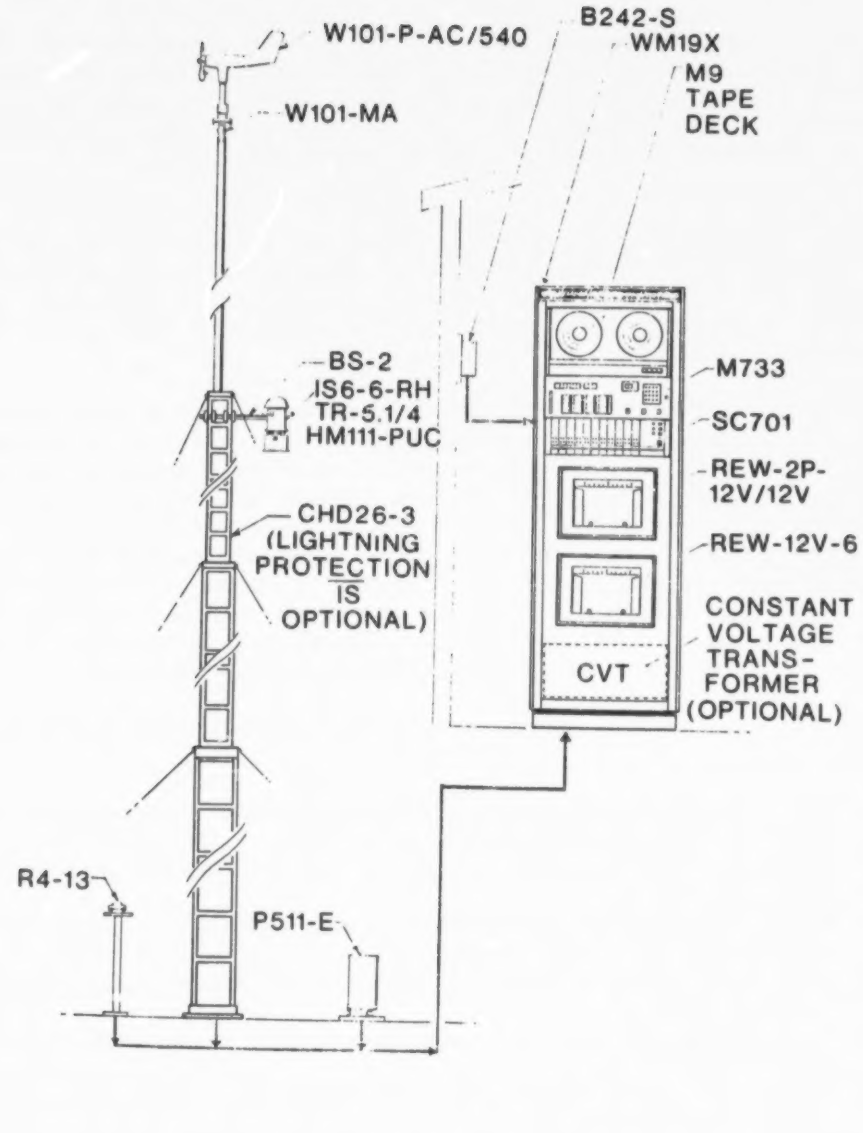

Figure 5. Schematic of meteorological system.

TABLE 18. ANALYTICAL METHODS FOR WASTEWATER ANALYSES: NON-VIABLE CONSTITUENTS

Analysis	Ref.[a]	Page	Remarks
Chemical oxygen demand (COD)	1	550	Sulfuric acid-Dichromate reflux
Biochemical oxygen demand (BOD)	1	543	5-day incubation at 20°C
Total suspended solids (nonfilterable)	2	268	Gooch crucible with glass fiber filtration dryness at 103 to 105°C
Residue on evaporation (ROE, total filterable)	2	92	Evaporation at 180°C
Total phosphorus (total P)	1	479	Persulfate digestion, stannous chloride color development
Nitrate plus nitrite as nitrogen (NO_3 + NO_2 - N)	1	423	Automated cadmium reduction followed by Diazo dye method
Ammonia nitrogen (NH_3 - N)	1	416	Automated Phenate method using optical density with spectrophotometer
pH	1	460	Electronic pH meter

[a] References:
1. AWWA, APHA, WPCF, Standard Methods for the Examination of Water and Wastewater. Fourteenth edition, American Public Health Association, Washington, D.C., 1976.
2. Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, Washington, D.C., 1974.

The system was in operation from May 21 to November 30. On approximately August 10, the electronic system was put out of commission (possibly by lightning) and did not being operating again until September 6.

SECTION 5

RESULTS AND DISCUSSION

HEALTH QUESTIONNAIRE SURVEY

Demographics of Survey Population

The 807 households (2,378 individuals) participating in the health questionnaire survey were distributed throughout the 1.6-km radius study area as shown in TABLE 19. The distances in TABLE 19 correspond to the sampling zones discussed in the METHODS section. It can be seen that the households were fairly equally distributed with regard to distance from the plant. Since the main health variable to be considered in this study was the incidence of infectious diseases relative to air quality, it was important to determine that the study population was composed of persons with similar demographic characteristics. Age, sex, race, socioeconomic status, and family size are all confounding variables in the incidence of most infectious diseases.

TABLE 19. DISTRIBUTION OF HEALTH QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Households		Individuals	
	No.	%	No.	%
0.0 - 0.8 km	269	33.3	847	35.6
0.8 - 1.2 km	267	33.1	791	33.2
1.2 - 1.6 km	271	33.6	740	31.1
Total	807	100.0	2,378	100.0

The distributions of the study population according to age, sex, race, family size, and household income (as an indicator of socioeconomic status) are given by distance of residence from the sewage treatment plant in TABLES 20 through 24. Comparisons (chi-square tests) of sex (TABLE 20) and income distributions (TABLE 21) were made to see if these demographic variables were related to distance of residence from the plant. The chi-square statistics for TABLES 20 and 21 were not significant ($p > 0.10$)

indicating that the sex and income distributions were similar in the three residential groups.

TABLE 20. PERCENT DISTRIBUTION OF SEX OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Percent distribution of sex		
	Female	Male	Total
0.0 - 0.8 km	50.3	49.7	100.0
0.8 - 1.2 km	54.4	45.6	100.0
1.2 - 1.6 km	52.8	47.2	100.0
Total	52.4	47.6	100.0

The age distributions (TABLE 22) indicated that the majority of the survey population was in the 19 to 59 year age group; less than 5 percent were under 6 years of age. Using a chi-square test, a significant difference ($p < 0.001$) was found between the age distributions for the three residential subpopulations. There was, for example, a high percent of persons over 59 years of age in the periphery of the study area. This was partially due to the inclusion of a large condominium complex occupied by older adults.

The race distributions (TABLE 23) were statistically significantly different (chi-square test, $p < 0.05$) for the three residential subpopulations. This difference was mainly due to extensive variations in the ethnicity of the non-white families, but these represented less than 8 percent of each of the three subpopulations.

TABLE 24 includes the distributions of family size for the three residential subpopulations. A significant difference (chi-square test, $p < 0.05$) was found between the family size in the three areas. One explanation for this observation was that the families residing 1.2 to 1.6 km from the plant (specifically those in the condominium complex) tended to consist of older families who were childless or whose children were no longer living at home.

Distribution of Factors Affecting Exposure of Survey Population

Several factors which could potentially affect the exposure of residents in the study area to airborne environmental constituents were examined for even distribution among the 807 households from which the Health Watch sample was obtained. Air conditioning in the home, for example, could reduce the amount of outdoor particles entering the home

TABLE 21. PERCENT DISTRIBUTION OF LEVEL OF INCOME OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Percent distribution of 1976 household income						Didn't know or refused to respond	Total	Median income ($)
	< $3,000	$3,000-6,999	$7,000-9,999	$10,000-14,999	$15,000-24,999	≥$25,000			
0.0 - 0.8 km	1.9	1.9	4.5	11.5	32.7	33.1	14.5	100.0	22,045
0.8 - 1.2 km	2.6	2.2	3.4	7.5	26.6	34.1	23.6	100.0	23,451
1.2 - 1.6 km	0.7	1.5	5.5	12.5	26.6	32.1	21.1	100.0	22,222
Total	1.7	1.9	4.5	10.5	28.6	33.1	19.7	100.0	22,316

TABLE 22. PERCENT DISTRIBUTION OF AGE OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Percent distribution of age[a,b]					Mean age, years
	<6 years	6-18 years	19-59 years	>59 years	Total	
0.0 - 0.8 km	5.1	20.4	60.2	14.3	100.0	37.0
0.8 - 1.2 km	4.2	18.9	57.2	19.7	100.0	39.2
1.2 - 1.6 km	5.4	16.8	51.6	26.1	100.0	40.6
Total	4.9	18.8	56.6	19.7	100.0	38.9

[a] Age was not given for seven or 0.03 percent of the 2,378 respondents.
[b] Chi-square independence test significant at 0.001 level.

TABLE 23. PERCENT DISTRIBUTION OF RACE OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Percent distribution of race[a,b]					Total
	White	Black american	Oriental	Latin american	Other	
0.0 - 0.8 km	92.6	0.4	4.1	1.1	1.9	100.0
0.8 - 1.2 km	94.0	0.4	1.1	1.5	3.0	100.0
1.2 - 1.6 km	94.1	2.6	2.2	0.0	1.1	100.0
Total	93.6	1.1	2.5	0.9	2.0	100.0

[a] Determined by observed race of household respondent.
[b] Chi-square independence test significant at 0.05 level.

TABLE 24. PERCENT DISTRIBUTION OF FAMILY SIZE OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Percent distribution of family size[a,b]									Total	Mean family size
	1	2	3	4	5	6	7	8	9		
0.0 - 0.8 km	8.2	30.5	22.3	23.4	10.8	3.7	0.4	0.4	0.4	100.0	3.1
0.8 - 1.2 km	7.1	36.0	25.1	20.2	9.4	1.1	0.7	0.4	0	100.0	2.9
1.2 - 1.6 km	14.0	41.0	17.0	20.3	3.7	3.0	0.4	0.4	0.4	100.0	2.7
Total	9.8	35.8	21.4	21.3	7.9	2.6	0.5	0.4	0.2	100.0	2.9

[a] Total number of related household members.

[b] Chi-square test for independence significant at 0.05 level.

(92). Length of residence in the study area would likely affect the duration of exposure to any environmental constituents in the study area, and certain occupations would be expected to influence susceptibility to certain acute infectious processes more than other occupations. The distributions for air conditioning, length of residence, and occupation by distance of residence from the plant are presented in TABLES 25 through 27. As shown in TABLE 25, over 92 percent of the homes, regardless of the residential area, had central or window-mounted air conditioning. No significant differences (chi-square test, $p > 0.1$) were found between the number of air conditioned homes in the three residential groups.

TABLE 25. PERCENT DISTRIBUTION OF AIR CONDITIONING[a] IN HOMES OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Air conditioning: Present in home	Air conditioning: Not present in home	Total
0.0 - 0.8 km	92.2	7.8	100.0
0.8 - 1.2 km	95.5	4.5	100.0
1.2 - 1.6 km	95.6	4.4	100.0
Total	94.4	5.6	100.0

[a] Central or window units.

The average length of residence in the study area was 11.7 years (TABLE 26). The length of residence distributions were statistically significantly different (chi-square test, $p < 0.001$) between the three residential groups. This again was partially due to those families living in the recently constructed condominium complex in the peripheral area.

Over 75 percent of the employed persons in the study population were white collar workers (TABLE 27). The distributions of occupations between the three residential groups were significantly different (chi-square test, $p < 0.05$).

Summary of Demographic and Exposure Characteristics of Health Questionnaire Survey Population

Briefly, the families participating in the questionnaire survey, regardless of their residence location in the study area, can be characterized as white (93.6 percent), middle class ($22,317 median income), white collar workers (76.8 percent), with an average family size of 2.9 people, and having lived in the study area for more than a decade (mean = 11.7 years).

TABLE 26. PERCENT DISTRIBUTION OF LENGTH OF RESIDENCE IN STUDY AREA OF FAMILIES IN QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT

Distance of residence from plant	Length of residence in study area, years[a]							Total	Mean, years
	<1	1-5	5-10	10-20	21-30	>30	Unknown		
0.0 - 0.8 km	7.1	22.0	14.5	38.5	16.8	1.2	0.0	100.0	12.3
0.8 - 1.2 km	7.1	21.2	17.1	36.4	16.8	1.1	0.3	100.0	12.2
1.2 - 1.6 km	8.0	27.7	23.5	24.2	15.5	1.1	0.0	100.0	10.7
Total	7.4	23.5	18.2	33.3	16.4	1.1	0.1	100.0	11.7

[a] Chi-square independence test significant at 0.001 level.

TABLE 27. PERCENT DISTRIBUTION[a] OF OCCUPATION[b] OF QUESTIONNAIRE SURVEY POPULATION BY DISTANCE OF RESIDENCE FROM PLANT[c]

Distance of residence from plant	Occupational Class								Total
	Professional, technical	Managers, adminis- trators	Clerical	Crafts- men	Opera- tives	Transport equipment operatives	Service workers	Don't know, no answer	
0.0-0.8 km	20.8	27.4	24.0	11.4	6.8	2.6	5.4	1.6	100.0
0.8-1.2 km	23.8	28.7	27.1	6.4	5.3	2.1	5.9	0.7	100.0
1.2-1.6 km	18.8	29.5	30.4	8.1	3.8	2.9	6.0	0.5	100.0
Total	21.1	28.5	27.1	8.6	5.3	2.5	5.7	1.0	100.0

[a] Based on 1,689 persons age 19 or older, employed full-time or part-time on date of interview.
[b] Based upon 1970 Bureau of the Census Occupational Classification System.
[c] Chi-square independence test significant at 0.05 level.

The analyses of the general characteristics of the subsets of the health questionnaire survey population according to location of residence in the study area have shown that there are minor significant differences in these subsets. Age, race, family size, length of residence, and occupation were significantly different, whereas sex, income, and home air conditioning were not. The differences, although minor, will be incorporated into later interpretation of the health data.

Prevalence of Chronic Conditions in the Survey Population

The concern about chronic conditions in the study population was two-fold: first, a number of chronic conditions have been associated with metals, gases, or infectious agents that are present in the environment; and second, individuals with chronic illness may be at a higher risk to acute infectious diseases than those without such conditions. TABLE 28 lists the chronic conditions specifically inquired about in the questionnaire survey and the corresponding number of conditions per 100 persons in the residential areas. For the 2,378 respondents, 2,006 chronic conditions were reported. The rates for respiratory conditions (26.6 per 100), cardiovascular conditions (20.4 per 100), gastrointestinal conditions (21.1 per 100' and other chronic conditions (28.0 per 100) combined for an overall prevalence of 96.6 conditions per 100 persons interviewed. It was not possible to assess these rates because they represent self-reported conditions experienced in the life-time of the survey participants; comparable data are not reported in the literature.

No association was found (one-way analysis-of-variance, $p > 0.05$) between the prevalence of chronic respiratory, chronic cardiovascular, or all chronic conditions and distance of residence from the plant. However, a significant difference (one-way analysis-of-variance, $p < 0.01$, followed by Duncan multiple range test) was observed between the prevalence of chronic gastrointestinal conditions in the 0.0 to 0.8-km and 1.2 to 1.6-km residence groups; persons living furthest from the plant had more gastrointestinal conditions than those living nearest the plant site. As shown in TABLE 22, the 1.2 to 1.6-km residence area had a higher percentage of persons over 59 years old (26.1 percent) than the other two residence areas (14.3 and 19.7 percent). This may be a possible explanation for the above observation.

Acute Illnesses Reported for Year Prior to Interview

TABLE 29 contains a summary of the rate of acute illnesses per 1,000 person-days for the year prior to the onset of the study. The average rate of 1.64 illnesses per 1,000 person-days was likely an underreporting since recall of short-term illness is probably unreliable, particularly if one family member responds for other family members. This was borne-out by several surveys over the past few decades (93) indicating that the average experience was 2.5 to 4.4 illnesses per 1,000 person-days.

One-way analyses-of-variance were performed for each type of illness as well as total illnesses to test for significant differences in average number of illnesses per 1,000 person-days between the three residential groups. No significant difference ($p > 0.05$) between groups was found for

TABLE 28. AVERAGE NUMBER OF REPORTED CHRONIC CONDITIONS PER 100 PERSONS BY DISTANCE FROM PLANT

Type of chronic condition	Distance of residence from plant			Total
	0.0-0.8 km	0.8-1.2 km	1.2-1.6 km	
Respiratory conditions	25.3	29.2	25.3	26.6
Allergies	15.9	19.6	16.8	17.4
Chronic bronchitis	4.5	3.7	2.6	3.6
Emphysema	1.1	1.4	0.9	1.1
Asthma	2.2	3.7	3.2	3.0
Tumor/cancer	0.3	0.3	0.3	0.3
Other	1.2	0.6	1.5	1.1
Cardiovascular conditions	18.4	21.2	21.9	20.4
High blood pressure	10.9	12.4	14.7	12.6
Stroke	1.2	0.5	0.4	0.7
Heart attack	2.7	2.5	2.8	2.7
Angina	1.5	2.6	1.2	1.8
Other	2.1	3.2	2.7	2.6
Gastrointestinal conditions	17.0	21.6	25.3[a]	21.1
Stomach/intest. ulcer	3.5	5.7	5.3	4.8
Colon ulcer	3.9	2.4	4.0	3.4
Diverticulosis	1.5	2.0	2.6	2.0
Gall bladder	4.3	5.7	7.6	5.8
Tumor/cancer	1.5	2.1	2.0	1.9
Other	2.2	3.7	3.8	3.2
Other cancers	2.1	2.6	3.6	2.7
Arthritis	9.9	9.6	11.5	10.3
Infectious hepatitis	1.0	1.2	1.4	1.2
Diabetes	4.4	5.1	3.2	4.2
Anemia	3.7	2.7	4.1	3.4
Other chronic conditions	6.6	6.1	5.9	6.2
Total	76.5	87.2	90.3	84.3

[a] Significantly greater (one-way analysis-of-variance test, $p < 0.05$, in conjunction with Duncan multiple range test) than that for 0.0-0.8 km residence group.

TABLE 29. AVERAGE NUMBER OF GENERAL TYPES OF ACUTE ILLNESSES PER 1,000 PERSON-DAYS DURING TWELVE MONTHS PRIOR TO SURVEY BY DISTANCE FROM PLANT

Distance of residence from plant	Type of acute illness				Total
	Respiratory	Gastro-intestinal	Eye/ear	Skin	
0.0 - 0.8 km	0.96	0.30	0.19	0.25	1.70
0.8 - 1.2 km	0.90	0.22	0.11	0.19	1.48
1.2 - 1.6 km	0.93	0.38	0.14	0.27	1.75
Total	0.93	0.30	0.16	0.25	1.64

respiratory, eye/ear, skin, or total acute illnesses. However, a significant difference ($p < 0.05$) in the average number of acute gastrointestinal illnesses per 1,000 person-days between the three residential groups was observed. A Duncan multiple range test indicated that the mean gastrointestinal illness rate for people residing 1.2 to 1.6 km from the plant was significantly greater than that for those residing 0.8 to 1.2 km from the plant.

HEALTH WATCH

Demographic Comparisons

Questionnaire-Only Households and Health Watch Participants--

Of the 807 households that participated in the questionnaire Health Watch to determine the incidence of health problems prospectively over an 8-month period. The remaining 517 households (1,509 individuals) were designated as "questionnaire-only" households. A demographic comparison of these two subsamples was made to determine whether the Health Watch participants adequately represented the entire questionnaire population ($n = 807$ households) and thus would be representative of the general population residing in the study area. The age, sex, race, family size, and income distributions for these two subsamples are presented in TABLES 30 through 34. Chi-square tests were performed and means and medians are included where appropriate. The demographic distributions were found to be similar ($p > 0.10$) for the two subsamples.

Health Watch Refusals and Their Replacements--

During recruitment of households for the Health Watch, 61 households (162 individuals) refused to participate in the study. In order to maintain the original sample size, the refusals were replaced with 54 alternate volunteer households (163 individuals). A demographic comparison of these two subsamples was performed to determine the differences between the refusals and their replacements.

The age, sex, race, family size, and income distributions for the Health Watch refusals and replacements are also presented in TABLES 30 through 34. No significant differences ($p > 0.1$) were found between the demographic distributions for the two subsamples when chi-square analyses were performed.

Health Watch Drop-Outs and Those Completing the Health Watch--

Of the 290 households that participated in the Health Watch, 44 (15 percent) dropped out during the course of the study. (Details of study attrition are in the METHODS section.) The 246 families completing the Health Watch included 724 individuals; the 44 drop-out families consisted of 145 individuals. The demographic characteristics of the drop-outs and those who completed the Health Watch are presented in TABLES 30 through 34. The distributions of age, sex, race, family size, and income were found to be the same ($p > 0.1$) using chi-square tests. Forty-three (17 percent) of the respondents from the households completing the study refused to divulge or did not know the household income, and this applied to 11 (25 percent) of the drop-out households.

TABLE 30. STUDY POPULATION BY AGE AND LEVEL OF PARTICIPATION

Level of participation	Age groups, years										Total	Mean age, years
	<6		6-18		19-59		>59		Unknown			
	No.	%[a]	No.	%	No.	%	No.	%	No.	%		
Questionnaire only	61	4.0	259	17.2	865	57.3	318	21.1	6	0.4	1,509	40.0
Health Watch participants	32	3.7	162	18.6	473	54.5	202	23.3	0	-	869	39.7
Subtotal	93	3.9	421	17.7	1,338	56.3	520	21.9	6	0.3	2,378	39.8
Health Watch refusals	4	2.5	25	15.4	86	53.1	47	29.0	-	-	162	44.3
Health Watch replacements	1	0.6	27	16.6	92	56.4	43	26.4	-	-	163	42.8
Subtotal	5	1.5	52	16.0	178	54.8	90	27.7	-	-	325	43.6
Dropped out of Health Watch	2	1.4	23	15.9	79	54.5	41	28.3	-	-	145	41.9
Completed Health Watch	30	4.1	139	19.2	394	54.4	161	22.2	-	-	724	39.2
Subtotal	32	3.7	162	18.6	473	54.4	202	23.2	-	-	869	39.7

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[a] Row percents.

TABLE 31. STUDY POPULATION BY SEX AND LEVEL OF PARTICIPATION

Level of participation	Sex				Total
	Male		Female		
	No.	%[a]	No.	%	
Questionnaire only	719	47.7	790	52.4	1,509
Health Watch participants	411	47.3	458	52.8	869
Subtotal	1,130	47.5	1,248	52.5	2,378
Health Watch refusals	76	46.9	86	53.1	162
Health Watch replacements	78	47.9	85	52.1	163
Subtotal	154	47.4	171	52.6	325
Dropped out of Health Watch	66	45.5	79	54.5	145
Completed Health Watch	345	47.6	379	52.4	724
Subtotal	411	47.3	458	52.7	869

[a] Row percents.

TABLE 32. STUDY HOUSEHOLDS BY RACE AND LEVEL OF PARTICIPATION

Level of participation	Race[a]										Total no. of households
	White		Black		Oriental		Spanish		Other		
	No.	%[b]	No.	%	No.	%	No.	%	No.	%	
Questionnaire only	485	93.8	7	1.4	12	2.3	4	0.8	9	1.7	517
Health Watch households	270	93.1	2	0.7	8	2.8	3	1.0	7	2.4	290
Subtotal	755	93.6	9	1.1	20	2.5	7	0.9	16	2.0	807
Health Watch refusals	59	96.7	1	1.6	0	-	0	-	1	1.6	61
Health Watch replacements	52	96.3	1	1.9	1	1.9	0	-	0	-	54
Subtotal	111	96.5	2	1.7	1	0.8	0	-	1	0.8	115
Dropped out of Health Watch	42	95.5	0	-	1	2.3	1	2.3	0	-	44
Completed Health Watch	228	92.7	2	0.8	7	2.9	2	0.8	7	2.9	246
Subtotal	270	93.1	2	0.7	8	2.8	3	1.0	7	2.4	290

[a] Determined by observed race of household respondent.

[b] Row percents.

TABLE 33. STUDY HOUSEHOLDS BY FAMILY SIZE AND LEVEL OF PARTICIPATION

Level of participation	Family size (no. of members in household)																		Total no. of house-holds	Mean family size
	1		2		3		4		5		6		7		8		9			
	No.	%[a]	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
Questionnaire only	51	9.9	183	35.4	117	22.6	109	21.1	43	8.3	11	2.1	1	0.2	1	0.2	1	0.2	517	2.92
Health Watch households	28	9.7	107	36.9	56	19.3	62	21.4	21	7.2	10	3.5	3	1.0	2	0.7	1	0.3	290	3.00
Subtotal	79	9.8	290	35.9	173	21.4	171	21.2	64	7.9	21	2.6	4	0.5	3	0.4	2	0.3	807	2.95
Health Watch refusals	6	9.8	28	45.9	13	21.3	9	14.8	5	8.2	0	---	0	---	0	---	0	---	61	2.66
Health Watch replacements	4	7.4	20	37.0	13	24.1	10	18.5	4	7.4	2	3.7	0	---	1	1.9	0	---	54	3.02
Subtotal	10	8.7	48	41.7	26	22.6	19	16.5	9	7.8	2	1.7	0	---	1	0.9	0	---	115	2.83
Dropped out of Health Watch	6	13.6	19	43.2	10	22.7	6	13.6	2	4.6	0	---	1	2.3	0	---	0	---	44	2.61
Completed Health Watch	22	8.9	88	35.8	46	18.7	56	22.8	19	7.7	10	4.1	2	0.8	2	0.8	1	0.4	246	3.07
Subtotal	28	9.7	107	36.9	56	19.3	62	21.4	21	7.2	10	3.4	3	1.0	2	0.7	1	0.3	290	3.00

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[a] Row percents.

TABLE 34. STUDY HOUSEHOLDS BY HOUSEHOLD INCOME AND LEVEL OF PARTICIPATION

Level of participation	Household income																Total no. of house-holds	Median income ($)
	<$3,000		$3,000-6,999		$7,000-9,999		$10,000-14,999		$15,000-24,999		≥$25,000		Unknown[a]		Refused[b]			
	No.	%[c]	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
Questionnaire only	11	2.1	11	2.1	19	3.7	56	10.8	152	29.4	163	31.5	32	6.2	73	14.1	517	22,171
Health Watch households	3	1.0	4	1.4	17	5.9	29	10.0	79	27.2	104	35.9	15	5.2	39	13.4	290	23,200
Subtotal	14	1.7	15	1.9	36	4.5	85	10.5	231	28.6	267	33.1	47	5.8	112	13.9	807	22,532
Health Watch refusals	1	1.6	3	4.9	4	6.6	9	14.8	11	18.0	19	31.1	3	4.9	11	18.0	61	21,364
Health Watch replacements	1	1.9	0	---	4	7.4	3	5.6	15	27.8	16	29.6	2	3.7	13	24.1	54	23,000
Subtotal	2	1.7	3	2.6	8	7.0	12	10.4	26	22.6	35	30.4	5	4.3	24	20.9	115	21,923
Dropped out of Health Watch	0	---	1	2.3	4	9.1	8	18.2	9	20.5	11	25.0	4	9.1	7	15.9	44	19,444
Completed Health Watch	3	1.2	3	1.2	13	6.4	21	8.5	70	28.5	93	37.8	11	4.5	32	13.0	246	23,857
Subtotal	3	1.0	4	1.4	17	5.9	29	10.0	79	27.2	104	35.9	15	5.2	39	13.4	290	23,228

[a] Respondent did not know household income.
[b] Respondent refused to answer income question.
[c] Row percents.

Summary--

The above three demographic comparisons of study population subsamples permit the following conclusions:

1) Health Watch participants were representative of the population residing in the study area.
2) Health Watch refusals were demographically similar to their replacements.
3) Health Watch families dropping out of the Health Watch were demographically similar to those completing the study.

Health Diary Data

The distribution of the types and number of illnesses reported and of the person-days observed during the 17 biweekly periods of the study are shown in TABLE 35. If all 869 persons who participated at any time in the study had participated for the full time, then 12,166 person-days of observation would have been expected for each biweekly period. At the beginning of the study (April 3), only 28.7 percent of the expected observations were made because family recruitment was still in progress. The maximal person-days observed was in the May 15-28 period when 86.3 percent of the expected was seen. Further attrition occurred, primarily in the next month. Variations in person-days observed during all periods were due to vacations and other short-term absences. Overall, 74.0 percent of the expected observations were made.

Because of these variations, illness rates were expressed as follows:

$$\frac{\text{number of illnesses}}{\text{number of person-days observed}} \times 1,000 = \text{illness rate per 1,000 person-days}$$

Thus, the total number of 1,572 illnesses reported during 153,026 person-days observed equaled a rate of 10.27 illnesses per 1,000 person-days as shown in TABLE 36. In general, these illness rates were consistent with the Health Interview Survey (HIS) for 1975-1976 reported by the National Center for Health Statistics (NCHS) (93). The rates shown in TABLE 36 were nearly 1.7 times higher than those reported by NCHS. This study and the HIS were not conducted in the same way and cannot be directly compared. It was possible that the Health Watch participants were more health conscious than the general population, because there was some degree of self-selection on the part of the Health Watch families even though they were demographically similar to a random sample of the study area population. The outcome of a self-selected, health conscious group would tend to result in over-reporting of illness. It is also emphasized that illness is defined here as any deviation from an expected healthy state, whereas NCHS defined illness as a condition limiting normal activity; consequently, the Health Watch was a highly sensitive measure of illness but not as specific or valid as the HIS.

TABLE 35. DISTRIBUTION OF REPORTED ILLNESSES[a] AND EXPOSURE DAYS BY DATA-COLLECTION PERIOD

Beginning date of 2-week data-collection period, 1977	No. of person-days of exposure[b]	No. of illnesses					
		Respiratory	Gastrointestinal	Eye-ear	Skin	All other[c]	Total
April 3	3,486	20	9	2	3	5	39
April 17	5,794	40	9	6	5	7	67
May 1	10,062	73	15	13	2	7	110
May 15	10,504	65	21	14	3	5	108
May 29	10,231	49	14	8	6	10	87
June 12	9,858	54	19	5	2	4	84
June 26	9,496	25	10	5	2	3	45
July 10	9,398	37	19	10	3	9	78
July 24	9,162	56	18	15	3	3	95
August 7	9,331	64	11	6	7	9	97
August 21	9,423	61	16	9	2	6	94
September 4	9,604	69	21	4	6	4	104
September 18	9,465	82	14	8	5	5	114
October 2	9,425	108	17	7	6	6	144
October 16	9,166	65	25	1	4	5	100
October 30	9,262	59	16	2	4	2	83
November 13	9,359	91	21	3	3	5	123
Total (%)	153,026	1,018 (64.8)	275 (17.5)	118 (7.5)	66 (4.2)	95 (6.0)	1,572 (100.0)

[a] Includes illnesses listed in TABLE 4.

[b] Total number of days all persons participating in Health Watch were present in the study area during the data-collection period.

[c] Includes other acute infections, exacerbations of chronic conditions and new chronic conditions.

TABLE 36. ILLNESS RATES[a] BY DATA-COLLECTION PERIOD

Beginning date of 2-week data-collection period, 1977	All illnesses[b]	Respiratory	Gastro-intestinal	Eye/ear	Skin	Other acute infections	Exacerbation of chronic condition	New chronic condition
April 3	11.42	5.85	2.64	0.59	0.88	0.59	0.88	--[c]
April 17	11.58	6.90	1.55	1.04	0.86	0.35	0.86	--
May 1	10.93	7.26	1.49	1.29	0.20	0.10	0.60	--
May 15	10.28	6.19	2.00	1.33	0.29	0.10	0.19	0.19
May 29	8.50	4.79	1.37	0.78	0.59	0.39	0.39	0.20
June 12	8.52	5.48	1.93	0.51	0.20	0.10	0.30	--
June 26	4.74	2.64	1.05	0.53	0.21	0.11	0.11	0.11
July 10	8.30	3.94	2.02	1.06	0.32	0.32	0.43	0.21
July 24	10.37	6.11	1.97	1.64	0.33	0.11	0.22	--
August 7	10.40	6.86	1.18	0.64	0.75	0.21	0.54	0.21
August 21	9.98	6.47	1.70	0.96	0.21	0.11	0.42	0.11
September 4	10.83	7.19	2.19	0.42	0.63	--	0.31	0.10
September 18	12.04	8.66	1.48	0.85	0.53	0.11	0.42	--
October 2	15.28	11.46	1.80	0.75	0.64	--	0.32	0.32
October 16	10.91	7.09	2.73	0.11	0.44	--	0.44	0.11
October 30	8.96	6.37	1.73	0.22	0.43	--	0.22	--
November 13	13.14	9.72	2.24	0.32	0.32	0.11	0.43	--
Total	10.28	6.66	1.80	0.77	0.43	0.14	0.39	0.10

[a] Illnesses per 1,000 person-days = $\frac{\text{no. of illnesses reported}}{\text{no. of person-days present}} \times 1{,}000$

[b] See TABLE 35 for number of illnesses.

[c] No cases reported.

Temporal Variations of Illnesses --

Respiratory illness rates were lower in the spring and summer than in the fall, reaching peak incidence in early October (TABLE 36). This relatively high occurrence appeared shortly after the beginning of school, coinciding with the increased exposure of children within the confinement of school rooms. The overall pattern of incidence of respiratory illnesses (Figure 6) was in consonance with current knowledge of seasonality of respiratory illness (93).

Seasonal variation was not observed for gastrointestinal illnesses, eye/ear illnesses, skin disease, other acute problems, exacerbation of chronic conditions, or new chronic conditions. Although seasonal variations for these illnesses was not expected, the rates for these illnesses were low (only gastrointestinal illness rates consistently exceeded one per 1,000 person-days) and temporal variations would have been an unlikely observation.

Illness Rates and Demographic Characteristics--

Illness rates were examined with respect to five demographic variables; age, sex, race, family size, and length of residence in the study area in order to determine which of these characteristics might be associated with risk of illness.

Age--Rates of all reported illnesses (TABLE 37) were highest in children under 14 years old, and the rate tended to decrease as age increased. The total illness rate for 3 to 5 year old children was significantly different (one-way analysis-of-variance, $p < 0.01$, in conjunction with Duncan multiple range test) from the total illness rate for the 14 to 18, 19 to 59, and over 59 year old groups.

Over two-thirds (68.0 percent) of all illnesses in all age groups were of respiratory nature. Gastrointestinal conditions were more common in the age groups 0 through 18 years than in older age groups. The other illness types were less age related and relatively infrequent in occurrence.

Sex--As seen in TABLE 38, the incidence rate of all illnesses reported for females (11.8 per 1,000 person-days) was significantly greater (t-test, $p < 0.01$) than that reported for males (8.6 per 1,000 person-days). A similar sex differential in illness was also observed by NCHS. It has also been reported (94) that women seek more health care, excluding visits pertaining to childbearing, than males. It was possible that the mother in a household was the Health Watch diary keeper and tabulated her own illnesses more completely than she did for other family members. It was also possible that women were in the home/community environment more than the male members of the household and were exposed to community airborne pollutants more consistently. The effect of air conditioning in the home, actual time spent at home and in the study area are confounding variables that cannot be addressed from the information available in the study.

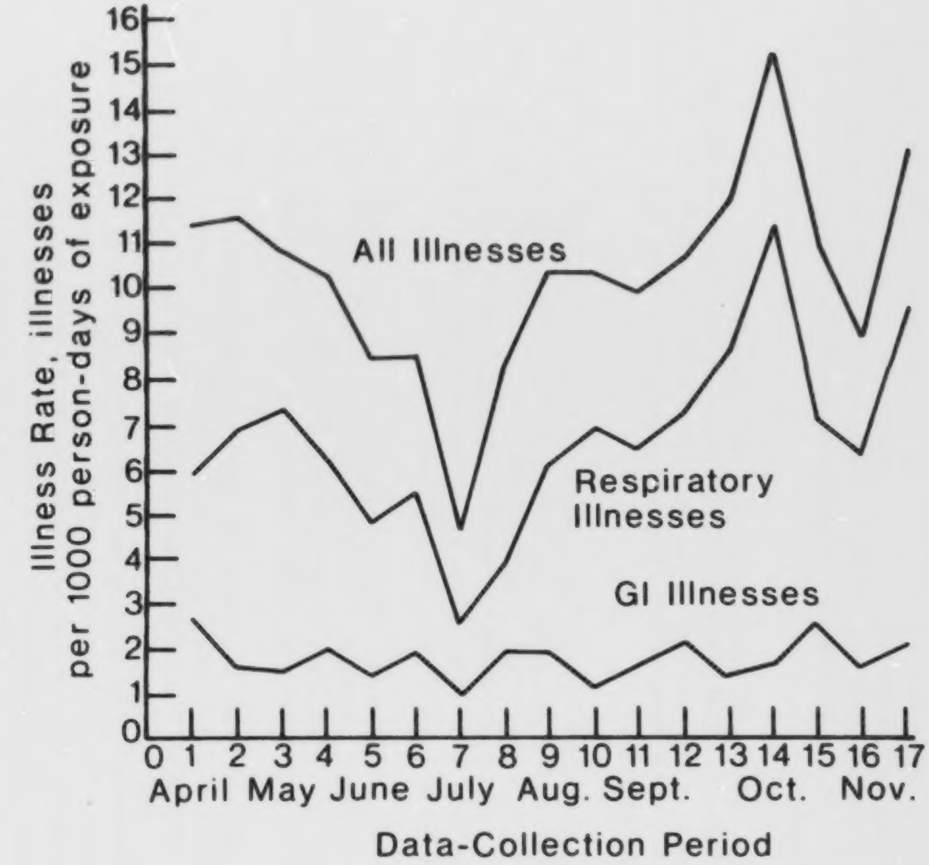

Figure 6. Seasonality of illness rates.

TABLE 37. ILLNESS RATES[a] BY AGE[b] AND TYPE OF ILLNESS

Type of illness	Age groups, years						Total (all ages)
	0-2	3-5	6-13	14-18	19-59	> 59	
Acute							
Respiratory	13.99[c]	16.09	10.63	7.63	6.02	4.61	6.66
Gastrointestinal	3.50	3.97	2.38	2.50	1.71	1.10	1.80
Eye/ear	2.33	0.88	0.89	0.66	0.59	1.13	0.77
Skin	--[d]	0.44	0.59	0.46	0.36	0.55	0.43
Other acute infections	--	0.22	0.15	0.13	0.10	0.23	0.14
Chronic							
Exacerbation of chronic condition	--	--	--	--	0.24	1.13	0.39
New chronic condition	--	0.22	--	0.13	0.07	0.17	0.10
Total (all illnesses)	19.83	21.82[e]	14.65	11.50	9.09	8.91	10.27
No. of people in age category	9	23	76	86	473	202	869

[a] See footnote "a" in TABLE 36.

[b] Age at beginning of Health Watch.

[c] See TABLE 35 for number of illnesses.

[d] No cases reported in this category.

[e] Significantly different ($p < 0.01$) from total illness rates for age groups 14-18, 19-59, and >59 years.

TABLE 38. ILLNESS RATES[a] BY SEX AND TYPE OF ILLNESS

Type of illness	Sex		Total (both sexes)
	Male	Female	
Acute			
Respiratory	5.67[b]	7.55	6.66
Gastrointestinal	1.48	2.09	1.80
Eye/ear	0.56	0.96	0.77
Skin	0.41	0.45	0.43
Other acute infections	0.04	0.23	0.14
Chronic			
Exacerbation of chronic condition	0.36	0.41	0.39
New chronic condition	0.08	0.11	0.10
Total (all illnesses)	8.61	11.80[c]	10.28
No. of people in sex category	411	458	869

[a] See footnote "a" in TABLE 36.

[b] See TABLE 35 for number of illnesses.

[c] Significantly ($p < 0.01$) greater than total illness rate for males.

Race--Illness rates by race are shown in TABLE 39. Since 92.7 percent of the families in the study were white, comparisons of illness rates according to ethnicity were not undertaken.

Family size--It has been generally found that the incidence of infectious diseases was proportional to family size (95). There was no apparent difference in illness rates in families ranging in size from one through nine members (TABLE 40) in this study. These illness rates however included numerous non-infectious, acute conditions as well as chronic conditions, which may mask the effect of family size on communicable illnesses.

Length of residence--It was also hypothesized that persons living in the study area for a short time might experience more illness because they are being exposed for the first time to sewage aerosols in the environment, whereas persons who have been exposed for longer periods of time were infected and are subsequently immune to these environmental agents. Not all reported illnesses are infectious in nature, and, as will be shown later, only about one of six reported illnesses in children can be associated with

TABLE 39. ILLNESS RATES[a] BY RACE AND TYPE OF ILLNESS

Type of illness[b]	Race[c]					Total
	White	Black	Oriental	Spanish	Other	
Acute						
Respiratory	6.68	5.76	6.20	6.88	6.74	6.66
Gastrointestinal	1.89	--[d]	1.94	--	0.42	1.80
Eye/ear	0.83	--	--	1.06	--	0.77
Skin	0.45	--	--	0.53	0.42	0.43
Other acute infections	0.14	--	--	--	0.21	0.14
Chronic						
Exacerbation of chronic condition	0.42	--	--	--	0.21	0.39
New chronic condition	0.10	--	--	--	0.21	0.10
Total	10.51	5.76	8.14	8.47	8.21	10.28
No. of households in race category	270	2	8	3	7	290

[a] See footnote "a" in TABLE 36.
[b] See TABLE 35 for number of illnesses.
[c] Determined by observed race of household respondent.
[d] No cases reported.

TABLE 40. ILLNESS RATES[a] BY FAMILY SIZE AND TYPE OF ILLNESS

Type of illness	Family size (no. of members in household)									Total (all family sizes)
	1	2	3	4	5	6	7	8	9	
Acute										
Respiratory	6.04[b]	6.49	4.98	7.72	7.72	5.54	6.85	4.94	10.28	6.66
Gastrointestinal	1.46	1.46	1.59	2.84	1.09	1.51	0.36	0.62	0.94	1.80
Eye/ear	1.04	0.93	0.94	0.65	0.52	0.76	--[c]	0.31	1.87	0.77
Skin	--	0.58	0.29	0.60	0.16	0.42	--	0.62	--	0.43
Other acute infections	0.42	0.17	0.11	0.16	0.10	--	--	0.31	--	0.14
Chronic										
Exacerbation of chronic condition	2.92	0.82	0.14	0.22	--	0.08	--	--	--	0.39
New chronic condition	--	0.17	--	0.13	0.10	0.08	--	--	--	0.10
Total (all illnesses)	11.87	10.61	8.04	12.33	9.60	8.39	7.21	6.80	13.08	10.28
No. of families in size category	28	107	56	62	21	10	3	2	1	290

[a] See footnote "a" in TABLE 36.
[b] See TABLE 35 for number of illnesses.
[c] No cases reported in this category.

an infectious agent. Although no association between length of residence and illness rate is readily apparent (TABLE 41), the inverse relationship of illness rate and length of residence may be real. Future studies should document this relationship, with laboratory data to confirm the incidence of infectious disease.

Microbiological Analyses of Specimens Collected

Stool specimens--

Eighty Health Watch participants provided stool specimens, as shown in TABLE 9, representing 44.0 percent of the expected number of providers. They submitted 541 stool specimens (17.7 percent of the total number of stool specimens expected), indicating that not even the 80 participants provided all the specimens expected. The purpose of requesting the stool specimens was multifold: to determine the frequency of microbiologically-confirmed self-reported illnesses; to establish the incidence of asymptomatic infections; and, particularly for the enteric viruses, to improve the chance of isolating certain viruses because virus shedding in the gastrointestinal tract is of longer duration (about one month) compared to shedding for a few days from oropharyngeal tissue (i.e., throat swabs).

Laboratory testing for bacteria included a search for many unusual isolates but not all possible pathogens such as enterotoxic Escherichia coli. The tissue culture systems used in the laboratory for virus isolation (APPENDIX A) were most sensitive for recovering adeno-, myxo- and enteroviruses and therefore excluded information on reoviruses and other entero-like agents.

As shown in TABLE 42, two Salmonella spp. were recovered from the 80 persons tested for eight months. One isolate was from a 5-year-old girl; the other was from an adult female. Neither had reported clinical illness. This was equivalent to an incidence rate of 3.75 cases per 100 person-years, which, compared to 12 cases per 100,000 person-years reported in the United States by the Center for Disease Control (96) was more than expected. The rate of permanent, asymptomatic carriers of salmonella in the United States is believed to be 0.2 to 5.0 per 100 of the normal population. Whether these two cases were carriers, or not, was not established.

Viruses isolated from the 541 stool specimens were members of three enterovirus groups. No adenoviruses or other cytopathic agents were recovered that could have been detected in the cell culture systems used (TABLE 42). Seven polioviruses were recovered, and all of these were from young children with a recent history of poliovirus immunization. One Coxsackievirus B3 was isolated from a child. The remaining 13 virus isolates were Echoviruses types 3, 6, 12, 22, and 25. The incidence of Echovirus infection was highest in the 3 through 6-year-old groups but occurred in the other age groups to 13 years old. Only one Echovirus infection occurred (Echovirus 12) in an adult. These coxsackie virus and Echovirus types recovered from this study group are commonly associated with respiratory-enteric illness or with diarrheal disease but often are asymptomatic infections.

TABLE 41. ILLNESS RATES[a] BY LENGTH OF RESIDENCE AT PRESENT ADDRESS

Type of illness[b]	Length of residence, years							Total
	<1	1-5	6-10	11-20	21-30	31-40	>40	
Acute								
Respiratory	7.77	8.11	6.57	5.40	6.91	4.47	4.98	6.65
Gastrointestinal	1.80	2.61	1.14	1.80	1.56	--[c]	1.66	1.80
Eye/ear	0.57	1.07	0.57	0.54	1.16	--	--	0.77
Skin	1.04	0.70	0.18	0.48	--	--	3.32	0.43
Other acute infections	--	0.09	0.07	0.16	0.25	0.56	--	0.14
Chronic								
Exacerbation of chronic condition	0.10	0.64	0.04	0.30	0.69	0.56	--	0.39
New chronic condition	--	0.09	0.14	0.10	0.11	--	--	0.10
Total (all illnesses)	11.27	13.30	8.72	8.79	10.68	5.59	9.97	10.27
No. of persons in residence category	56	206	159	289	145	11	2	868[d]

[a] See footnote "a" in TABLE 36.
[b] See TABLE 35 for number of illnesses.
[c] No cases reported in this category.
[d] Length of residence unknown for one person.

TABLE 42. FREQUENCY DISTRIBUTION OF ORGANISMS ISOLATED FROM STOOL SPECIMENS[a] BY AGE OF PARTICIPANT[b]

Isolates	Age groups, years						Total
	0-2	3-4	5-6	7-12	13-18	19-59	
Stool specimens							
1) No. of people asked to give specimens	8	14	20	69	24	45	180
2) No. people who gave at least one	6	10	10	23	8	23	80
3) No. specimens obtained	43	73	72	154	46	153	541
Bacterial isolates[c]							
1) Salmonella	0	0	1	0	0	1	2
Viral isolates[c]							
1) Polio 1	3	0	0	0	0	0	3
2) Polio 3	3	0	0	1	0	0	4
3) Coxsackie B3	0	0	1	0	0	0	1
4) Echo 3	0	0	1	3	0	0	4
5) Echo 6	0	1	1	0	0	0	2
6) Echo 12	0	1	1	0	0	1	3
7) Echo 22	1	0	1	0	0	0	2
8) Echo 25	0	1	1	0	0	0	2
Total viral	7	3	6	4	0	1	21
Total stool[c] isolates	7	3	7	4	0	2	23

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[a] Specimens were requested on a biweekly basis of children 12 years of age and under and of one adult in each family thereof. Specimens were obtained from May, 1977 through November, 1977.

[b] Age at beginning of Health Watch.

[c] For cases of multiple consecutive isolations of a single type of organism for one person, only the first isolation was tabulated.

An interpretation of the incidence of these laboratory-confirmed infections based on examination of stool specimens is, at best, crude. The incidence of Salmonella spp. in stool specimens has been considered above, and the poliovirus isolates were vaccine-related. The recovery of 14 coxsackie viruses and Echoviruses from 80 persons submitting 541 specimens over an 8-month period yields a crude rate of 17.5 enterovirus isolations per 100 persons per 8 months. The Center for Disease Control publishes frequencies of enterovirus infections for the United States, but these are based on isolations from severely ill, sometimes hospitalized populations.

Two studies conducted by Honig et al. (97) and Gelfand et al. (98) showed that the percentage of healthy children shedding enteroviruses ranged from 4.6 to 14.9 percent. The Health Watch study period covered those seasons of the year in which enterovirus infection rates are expected to be highest, accounting for the rate found here being in the upper limits of the expected rate.

Throat Specimens--

Of the 111 children 12 years old and under in families recruited into the Health Watch, 81 submitted 757 throat specimens for an average of 9.3 specimens per child during the study (TABLE 43). Theoretically, 17 specimens could have been collected from each participating child; actually, nearly 55 percent of the expected number of throat specimens were collected. Compared with the 17.7 percent of expected stool specimens collected, it is apparent that providing throat swabs was more acceptable than submitting fecal samples. It was also noted that the age distribution of the 81 children providing throat specimens was similar to that of the original 111 children in the recruited families.

A total of 177 bacterial and viral isolates was made from the 757 throat specimens received. On the average, 4.5 bacterial isolates were recovered from each child in the 0 to 2 year age group, 2.7 per child in the 3 to 4 year age group, and 1.8 in the 5 to 12 age group. A similar decrease in isolation with increasing age was also possible for viral infections but the numbers were too small to be significant.

Of the 20 different bacterial types isolated, Klebsiella pneumoniae, Staphylococcus aureus, and Enterobacter spp. were the most frequently recovered in the 0 to 2 and 3 to 4 year age groups. S. aureus was the most frequent isolate in the 5 to 12 year old group, followed by Beta-hemolytic streptococci. The number of different bacterial genera isolated was the smallest in the youngest age group and more different genera were recovered with increasing age.

Only four virus isolates were recovered: three Echovirus 6 were isolated in the 3 to 12 year olds, and one Adenovirus 2 in the 5 to 12 year old group. No viral isolates were made in children 2 years old or younger. Hemadsorption tests were done on all cell cultures inoculated with these specimens and none were positive, suggesting that influenza, para-influenza,

TABLE 43. FREQUENCY DISTRIBUTION OF ORGANISMS ISOLATED FROM THROAT SPECIMENS[a] BY AGE OF PARTICIPANT[b]

Isolates	Age groups, years						Total	
	0-2		3-4		5-12			
	No.	Rate[c]	No.	Rate	No.	Rate	No.	Rate
Throat specimens								
1) No. people asked to give specimens	8		14		89		111	
2) No. people who gave at least one	6		11		64		81	
3) No. specimens received	48		108		601		757	
Bacterial isolates[d]								
1) *Staphylococcus aureus*	6	100.0	8	72.7	56	87.1	70	86.4
2) β-Streptococcus, Group A	0	0.0	1	9.1	14	22.4	15	18.5
3) β-Streptococcus, not A or D	0	0.0	2	18.2	17	26.5	19	23.5
4) *Salmonella enteritidis* (Newport)	0	0.0	1	9.1	0	0.0	1	1.2
5) *Klebsiella ozaenae*	2	33.3	0	0.0	0	0.0	2	2.5
6) *Klebsiella pneumoniae*	9	150.0	2	18.2	4	6.2	15	18.5
7) *Escherichia coli*	2	33.3	1	9.1	5	7.8	8	9.9
8) *Enterobacter aerogenes*	0	0.0	1	9.1	0	0.0	1	1.2
9) *Enterobacter agglomerans*	1	16.7	2	18.2	6	9.4	9	11.1
10) *Enterobacter cloacae*	4	66.7	6	54.5	5	7.8	15	18.5
11) *Enterobacter hafniae*	0	0.0	0	0.0	1	1.6	1	1.2
12) *Serratia liquefaciens*	0	0.0	1	9.1	3	4.7	4	4.9
13) *Serratia marcescens*	0	0.0	0	0.0	1	1.6	1	1.2
14) *Serratia rubidaea*	0	0.0	0	0.0	1	1.6	1	1.2
15) *Aeromonas hydrophilia*	0	0.0	2	18.2	1	1.6	3	3.7
16) *Citrobacter diversus*	0	0.0	1	9.1	0	0.0	1	1.2
17) *Citrobacter freundii*	2	33.3	0	0.0	0	0.0	2	2.5
18) *Pseudomonas* spp.	0	0.0	1	9.1	2	3.1	3	3.7
19) CDC, Group IV, C-2	0	0.0	0	0.0	1	1.6	1	1.2
20) CDC, Group V, E-1	1	16.7	0	0.0	0	0.0	1	1.2
Total bacterial	27		29		117		173	
Viral isolates[d]								
1) Adenovirus 2	0		0		1		1	
2) Echovirus 6	0		2		1		3	
Total viral	0		2		2		4	
Total throat isolates	27		31		119		177	

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[a] Specimens were requested on a biweekly basis from children 12 years of age and under. Specimens were obtained from May, 1977 through December, 1977.

[b] Age at beginning of Health Watch.

[c] Number of isolates per 100 persons.

[d] For cases of multiple consecutive isolations of a single type of organism for one person, only the first isolation was tabulated.

measles, or mumps virus infections had not occurred in this population.

The spectrum of the bacterial isolates listed in TABLE 43 deserves brief comment but does not completely lend itself to a statement of expectation. The Beta-hemolytic streptococci incidence rates observed here were as expected; these are rare infections in infants and pre-school age children, reaching rates of 10 to 25 percent in a school-age population (9). Man is the main reservoir, and environmental sources are of little importance. Staphylococcus aureus is a potential pathogen for man since it is found in both respiratory secretions and feces and frequently in sewage. Approximately 20 percent of children are infected during any one period of time, and the carrier rate is approximately 30 percent in most normal populations. The remainder of the spectrum can be generally classified as enterobacteria: most are considered normal flora of the gastrointestinal tract of man and have limited pathogenic ability there. All would be expected in sewage influents but some are also free-living in soil and water. Salmonella enteritidis is a definite pathogen for man causing paratyphoid fever, but a minimum of 100,000 organisms is needed to cause overt disease; it is not free-living and is found in sewage. The 17 isolates of Klebsiella pneumoniae and ozaenae from 81 children were more than expected. Although these organisms can be part of the normal flora of the intestinal tract, recovery from the oropharynx of a general population is usually sporadic and rare (99). Randall and Ledbetter (7) suggested that the capsulated species of Klebsiella, which both of these species are, was able to survive in sewage aerosols better than noncapsulated species by virtue of the capsule being protective. The Serratia spp. recovered are widespread in nature and are usually associated with short-term respiratory conditions. Although they can be found in sewage, there are other environmental sources of the organism (i.e., soil). Escherichia coli becomes a prominent member of the intestinal flora in the first few days of life and is frequently present in the first few years of life, which was the general observation here. The Aeromononas, Citrobacter, and Pseudomonas spp. are free-living agents in soil, water, and sewage and have little, or only opportunistic, pathogenicity for man. An overall incidence rate of about 4 percent for each of these three genera from throat swabs in a general population was not unexpected although comparative data have not been found in the literature. The Enterobacter spp. are free-living and are infrequent residents of the intestinal or respiratory tract. The recovery of five separate isolates from the six children in the 0 to 2 year age group was more than expected. Hoeprich (100) states that incidence rates of 21 to 23 percent have been observed. The two isolates referred to as CDC Groups IV and V were unusual Gram-negative, non-lactose fermenters that have been previously identified by the Center for Disease Control, but are of unknown significance and unassociated with human illness.

In summary, 173 separate, non-normal flora, bacterial isolates were recovered from routine throat swab specimens of 81 children one through 12 years old. In contrast, only two unusual bacterial isolates were identified in stool specimens from persons 0 through 59 years of age. Virus isolates were about three times more frequent from stools (excluding the polioviruses associated with immunization) than from throat specimens. The recovery of more enteroviruses from stool than from throat specimens was expected because infections of the oropharynx persist for only a few days whereas the infections continue in the intestinal tract for a month or more (whether or not there is associated clinical illness) increasing the chance of recovery when biweekly specimens are obtained. The information derived from this microbiological survey of throat and stool specimens did not allow a statement of the significance of the findings because of the small number of participants involved and of bacteria and viruses recovered. The findings were of value for descriptive purposes for consideration later when the air quality data are analyzed.

Comparison of Bacterial Isolation and Apparent and Inapparent Illness

Some of the reasons for obtaining specimens from the Health Watch population were to determine the frequency of laboratory confirmation of reported illness and to obtain some information on the frequency of inapparent infections. TABLE 44 summarizes the comparison of isolating bacteria from throat swabs with the reported occurrence of respiratory illness. It can be seen that 12.0 percent of all throat specimens were obtained when a respiratory illness was reported. Thus, about one-sixth of the reported respiratory illnesses could be confirmed by bacterial isolation. The majority (88.0 percent) of specimens were obtained from persons without reported illness; about one-fifth were culture positive and the remainder culture negative. This comparison suggested that one of five children had an inapparent infection sometime during the study.

TABLE 44. COMPARISON OF THROAT BACTERIAL CULTURE RESULTS WITH REPORTED RESPIRATORY ILLNESS

Throat bacterial culture result	Reported respiratory illness		Total
	Yes	No	
Positive	2.1%[a] (confirmed infections)	17.2% (inapparent infections)	19.3%
Negative	9.9%	70.8%	87.3%
Total	12.0%	88.0%	100.0%[b]

[a] All percents are percent of total throat bacteria cultures.
[b] N = 757 throat bacterial cultures.

Serosurvey of Health Watch Participants

Prevalence of Viral Antibodies--

Blood samples were collected only from persons over 6 years old. As shown in TABLE 45, persons providing samples at the beginning and at the end of the study (paired bloods) were in this analysis to be able to compare the prevalence of antibody-positive persons with the incidence of persons developing antibody during the study period.

Of the 869 Health Watch participants, 32 (3.7 percent) were under 6 years of age; 115 (13.2 percent) gave one blood sample; and 404 (46.5 percent) gave no blood (TABLE 45). Consequently the remaining 318 (36.6 percent) giving the paired blood are considered here. The age distribution of the donors and non-donors was significantly different (chi-square test, $p < 0.001$); only 12.6 percent of the donors were 6 to 18 years of age whereas 26.7 percent of the non-donors were in this age group. Overall, the mean age of the paired blood donors was significantly higher ($p < 0.05$) than that for the non-donors. The sex distributions shown in TABLE 46 were not significantly different (chi-square test, $p > 0.05$) between the three serosurvey participant groups.

The first blood samples of the paired bloods were analyzed for neutralizing (type-specific) antibody to three types of polioviruses, five types of coxsackie viruses B, and four types of Echoviruses (TABLES 47 and 48). Antibody titers in the respective sera obtained at the beginning of the study were used to determine the rates of previous infections by these specific viruses and the number of persons susceptible to each of these agents.

TABLE 47 summarizes the prevalence of antibody data for the coxsackie viruses and Echoviruses by age groups. The percentage of donors having antibody for each of the coxsackie viruses B in each age group suggests that infections with B1 occur in the 14 to 18 year age group. Infections with types B2, B3, and B4 occur at all ages. Infections with B5 occur in all age groups and there may have been an epidemic of B5 virus infections a decade earlier involving school-age children (6 to 13 years of age). Overall, there had been more previous infections with B4 and least with B1 viruses. Approximately one-third of the donors had previous infections with Echoviruses. Most of the initial infections by Echoviruses 3 and 6 appear to occur before 6 years of age, whereas Echovirus 9 infections occurred in all age groups. Echovirus 12 infections occurred primarily in the adult age groups.

Overall, 38.3 percent of the donors had experience with one or more of the coxsackie viruses and Echoviruses in the past. Since there is no vaccine for any of these viruses, these titers are probably due to natural infection by wild viruses acquired by the fecal-oral route from infected persons or from the environment. In contrast, the prevalence of antibody to the three poliovirus strains (TABLE 48) could be due to infections by wild virus or by immunization. It can also be seen that, on the average, over 88 percent of the donors have antibody to one or more of the polioviruses regardless of age.

Serological Evidence of the Incidence of Viral Infections--

Knowing the prevalence of antibody to the nine enteroviruses listed in TABLE 47, it was possible to identify the susceptibles in the study

TABLE 45. AGE DISTRIBUTION OF SEROSURVEY PARTICIPANTS

No. of blood samples collected[a]	Age groups, years[b,c]						Total no. of persons	Mean age, years
	6-18		19-59		> 59			
	No.	%	No.	%	No.	%		
Paired	40	12.6	192	60.4	86	27.0	318	45.2[d]
Single	14	12.2	72	62.6	29	25.2	115	41.4
None	108	26.7	209	51.7	87	21.5	404	38.1
Total	162	19.3	473	56.5	202	24.1	837	41.3

[a] Thirty-two of the 869 Health Watch participants were under 6 years old, and blood samples were not requested of them.

[b] Age at beginning of Health Watch.

[c] Chi-square analysis showed significant difference ($p < 0.001$) between age distributions for the three serosurvey participation groups.

[d] Significantly different (analysis-of-variance test, $p < 0.05$) from mean age of those who did not provide any blood samples.

TABLE 46. SEX DISTRIBUTION OF SEROSURVEY PARTICIPANTS

No. of blood samples collected	Sex				Total no. of persons
	Male		Female		
	No.	%	No.	%	
Paired	157	49.4	161	50.6	318
Single	62	53.9	53	46.1	115
None	178	44.1	226	55.9	404
Total	397	47.4	440	52.6	837[a]

[a] Thirty-two of the 869 Health Watch participants were under 6 years old, and blood samples were not requested of them.

TABLE 47. PREVALENCE[a] OF ANTIBODY TO NINE COXSACKIEVIRUSES AND ECHOVIRUSES BY AGE

	Age groups, years									
	6-13		14-18		19-59		> 59		Total	
Virus	No.[b]	%[c]	No.	%	No.	%	No.	%	No.	%
Coxsackie B1	0	0.0	5	20.0	33	17.5	11	12.5	49	15.4
Coxsackie B2	3	17.6	7	28.0	87	46.3	47	53.4	144	45.3
Coxsackie B3	3	17.6	10	40.0	92	48.9	41	46.6	146	45.9
Coxsackie B4	4	23.5	12	48.0	127	67.5	67	76.1	210	66.0
Coxsackie B5	5	29.4	12	48.0	69	36.7	17	19.3	103	32.4
Total Coxsackie	15	--	46	--	408	--	183	--	652	--
Echo 3	7	41.2	8	32.0	55	29.2	49	55.7	119	37.4
Echo 6	7	41.2	8	32.0	78	41.5	49	55.7	142	44.6
Echo 9	2	11.8	5	20.0	60	31.9	28	31.8	95	29.9
Echo 12	0	0.0	1	4.0	60	31.9	36	40.9	97	30.5
Total Echo	16	--	22	--	253	--	162	--	453	--
Total no. positive	31	--	68	--	661	--	345	--	1105	--
No. of donors	17	--	25	--	188	--	88	--	318	--

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[a] Based on neutralizing antibody assay of first blood samples of paired samples obtained.

[b] Number of blood samples where initial antibody titer was $\geq$ 10.

[c] $$\text{Percent} = \frac{\text{no. positive for indicated virus}}{\text{no. of sera tested for specific age group.}}$$

TABLE 48. PREVALENCE[a] OF ANTIBODY TO THREE POLIOVIRUSES BY AGE

	Age groups, years									
	6-13		14-18		19-59		> 59		Total	
Virus	No.[b]	%[c]	No.	%	No.	%	No.	%	No.	%
Polio 1	16	94.1	24	96.0	177	94.1	78	88.6	295	92.8
Polio 2	16	94.1	25	100.0	178	94.7	74	84.1	293	92.1
Polio 3	13	76.5	22	88.0	155	82.4	68	77.3	258	81.1
Total	45	--	71	--	510	--	220	--	846	--
No. of donors	17	--	25	--	188	--	88	--	318	--

[a] Based on neutralizing antibody assay of first blood samples of paired samples obtained.

[b] Number of blood samples where initial antibody titer was $\geq$ 10.

[c] $$\text{Percent} = \frac{\text{no. positive for indicated virus}}{\text{no. of sera tested for specific age group.}}$$

population. It was necessary to calculate the number of susceptibles for each virus under consideration, since any one person could be immune to one virus and susceptible to another virus. The following equations were used in TABLE 49:

1) no. susceptible + no. immune = total paired blood donors

2) no. susceptible = (no. of persons with initial titer <10)
plus
(all other persons with fourfold rise)

The incidence of Coxsackievirus B4 infections was the highest observed, 17.97 per 100 persons, whereas the B1 rate was the lowest, 1.48 per 100 persons. The listing of the number of persons immune and susceptible to the coxsackieviruses emphasizes that the majority of persons were susceptible to these agents, except for Coxsackievirus B4.

The infection rates for Echoviruses 3, 6, 9, and 12 were similar to each other and were generally lower than those observed for the coxsackieviruses. The number of susceptibles was similar to the number susceptible to the coxsackieviruses.

The incidence of these viral infections was then examined by age groups (TABLE 50). Infections by Coxsackieviruses B1 and B2 were not observed in the 6 through 18 year old group, but occurred in all other age categories. The incidence of B3 infections was similar in all age groups, whereas B4 infection rates increased remarkably with increasing age to a maximum of over 30 per 100 persons over 59 years old. Coxsackievirus B5 infections were relatively more frequent in children and adults than in the over 59 year old group.

Echovirus 3, 6, and 9 infection rates were similar in all age groups; Echovirus 12 infections were not observed in the 6 through 18 year old group and the rate increased from about 4 per 100 in the 19 through 59 year old group to 10 per 100 in the over 59 year old group. With only a few exceptions, the number of susceptible persons in each age group exceeded the number immune. The prevalence and incidence data presented here for these few infectious diseases are of important descriptive nature, and they are not intended for statistical interpretation since a hypothesis for these data alone was not the purpose of this portion of the study. Biometric analyses of these data will be applied when they are considered with the environmental air quality data.

ENVIRONMENTAL MONITORING PROGRAM

Introduction

The environmental monitoring program was designed to answer two questions: (1) What are the exposures of people living in the study area to air pollutants?; (2) Is the Metropolitan Sanitary District's North Side

TABLE 49. INCIDENCE OF VIRAL INFECTIONS AMONG SUSCEPTIBLE BLOOD DONORS

Virus antigen	No. of persons immune[a]	No. of persons susceptible[b]	No. of persons seroconverting[c]	Incidence[d] of viral infections
Coxsackie B1	48	270	4	1.48
Coxsackie B2	137	181	12	6.63
Coxsackie B3	140	178	15	8.43
Coxsackie B4	190	128	23	17.97
Coxsackie B5	98	220	9	4.09
Echo 3	119	199	7	3.52
Echo 6	140	178	8	4.49
Echo 9	94	224	3	1.34
Echo 12	94	224	10	4.46

[a] No. of persons with initial antibody titer $\geq$ 10 minus no. of persons with fourfold rise whose initial titer was >10.

[b] No. of persons with initial antibody titer < 10 plus all other persons with fourfold rise.

[c] All persons with fourfold rise in antibody titer.

[d] Incidence of viral infections = $\frac{\text{no. of persons seroconverting}}{\text{no. of persons susceptible}}$ x 100.

TABLE 50. INCIDENCE OF VIRAL INFECTIONS AMONG SUSCEPTIBLE BLOOD DONORS BY AGE

Virus antigen	Age groups, years											
	6-18				19-59				> 59			
	No. of immune persons[a]	No. of susc. persons[b]	No. of persons seroconverting[c]	Incid. of viral infection[d]	No. of immune persons	No. of susc. persons	No. of persons seroconverting	Incid. of viral infection	No. of immune persons	No. of susc. persons	No. of persons seroconverting	Incid. of viral infection
Coxsackie B1	5	35	0	0.00	32	160	3	1.87	11	75	1	1.33
Coxsackie B2	10	30	0	0.00	82	110	9	8.18	45	41	3	7.32
Coxsackie B3	12	28	2	7.14	89	103	9	6.74	39	47	4	8.51
Coxsackie B4	15	25	1	4.00	114	78	14	17.95	60	26	8	30.77
Coxsackie B5	16	24	1	4.17	65	127	7	5.51	17	69	1	1.45
Echo 3	15	25	2	8.00	55	137	4	2.92	49	37	1	2.70
Echo 6	14	25	1	4.00	77	115	5	4.35	48	38	2	5.26
Echo 9	7	23	1	3.03	59	133	1	0.75	28	58	1	1.72
Echo 12	1	39	0	0.00	58	134	5	3.73	35	51	5	9.80

[a] No. of persons with initial antibody titer $\geq$ 10 minus no. of persons with fourfold rise whose initial titer was > 10.

[b] No. of persons with initial antibody titer < 10 plus all other persons with fourfold rise.

[c] All persons with fourfold rise in antibody titer.

[d] Incidence of viral infections = $\frac{\text{no. of persons seroconverting}}{\text{no. of persons susceptible}} \times 100.$

Sewage Treatment Plant a source of air pollution for the surrounding community?

The following nine data sets were organized to help answer these questions:

1) Hourly Meteorology, which contains hourly observations of temerature, humidity, wind speed, wind direction, solar radiation, ultraviolet radiation, and visibility;
2) Averaged Meteorology, which contains 24-hour averaged temperature, humidity, solar radiation, UV radiation, visibility, and 24-hour vector-averaged wind speed and direction;
3) Gaseous Air Pollution, which includes 24-hour integrated averages of sulfur dioxide, nitrogen dioxide, hydrogen sulfide, chlorine, and ammonia;
4) Particulate Air Pollution, which includes 24-hour integrated averages of total suspended particulates, sulfates, nitrates, vanadium, chromium, manganese, nickel, copper, arsenic, cadmium, selenium, tin, antimony, mercury, and lead;
5) Total Viable Particles (total aerobic bacteria-containing particles), (collected with six-stage Andersen samplers) which includes plate counts, total corrected plate count, total viable concentrations, identification of plate counter, pump number, sampler number, and the humidity at the sampling location;
6) Total Coliform Particles, (collected with Andersen six-stage samplers) which contain the same parameters as the total viable particle data set;
7) Viable Sewage, which contains measures of total aerobic bacteria, total coliform, and fecal coliform concentrations sampled from the inlet of aeration battery B;
8) Non-viable Sewage, which contains measures of $SO_4^=$, NO_3^-, V, Cr, Mn, Ni, Cu, As, Cd, Se, Sn, Sb, Hg, Pb;
9) Plant Operating Characteristics, which includes daily totals of sewage throughput, total air used in aeration process, total flow through the aeration batteries and 24-hour composites of organic and ammonia nitrogen, dissolved oxygen, 5-day BOD, and suspended solids in the raw sewage, preliminary sewage, and final effluent.

TABLE 51, Table of Nomenclature, lists all variables that appear in the data sets with the abbreviations used in this analysis. A complete listing of all environmental data is given in APPENDIX E. The plant operating data is available from the Metropolitan Sanitary District of Chicago (MSD).

Summary of Environmental Data

Meteorology--

A detailed record of the meteorological conditions during the study period was an important component of both the environmental sampling and data analysis efforts. Three sources contributed to this record. They were

TABLE 51. TABLE OF NOMENCLATURE

NH3CONC -------------- Ammonia in air concentration $(\mu g/m^3)$
CL2CONC -------------- Chlorine in air concentration $(\mu g/m^3)$
H2SCONC -------------- Hydrogen sulfide in air concentration $(\mu g/m^3)$
NO2CONC -------------- Nitrogen dioxide in air concentration $(\mu g/m^3)$
SO2CONC -------------- Sulfur dioxide in air concentration $(\mu g/m^3)$
TSP ------------------ Total suspended particulates $(\mu g/m^3)$
NO3CONC -------------- Nitrate in air concentration $(\mu g/m^3)$
SO4CONC -------------- Sulfate in air concentration $(\mu g/m^3)$
VCONC ---------------- Vanadium in air concentration $(\mu g/m^3)$
CRCONC --------------- Chromium in air concentration $(\mu g/m^3)$
MNCONC --------------- Manganese in air concentration $(\mu g/m^3)$
NICONC --------------- Nickel in air concentration $(\mu g/m^3)$
CUCONC --------------- Copper in air concentration $(\mu g/m^3)$
ASCONC --------------- Arsenic in air concentration $(\mu g/m^3)$
SECONC --------------- Selenium in air concentration $(\mu g/m^3)$
CDCONC --------------- Cadmium in air concentration $(\mu g/m^3)$
SNCONC --------------- Tin in air concentration $(\mu g/m^3)$
SBCONC --------------- Antimony in air concentration $(\mu g/m^3)$
HGCONC --------------- Mercury in air concentration $(\mu g/m^3)$
PBCONC --------------- Lead in air concentration $(\mu g/m^3)$
NH3LIMIT ------------- Ammonia in air detection limit $(\mu g/m^3)$
CL2LIMIT ------------- Chlorine in air detection limit $(\mu g/m^3)$
H2SLIMIT ------------- Hydrogen sulfide in air detection limit $(\mu g/m^3)$
NO2LIMIT ------------- Nitrogen dioxide in air detection limit $(\mu g/m^3)$
SO2LIMIT ------------- Sulfur dioxide in air detection limit $(\mu g/m^3)$
VLIMIT --------------- Vanadium in air detection limit $(\mu g/m^3)$
CRLIMIT -------------- Chromium in air detection limit $(\mu g/m^3)$
MNLIMIT -------------- Manganese in air detection limit $(\mu g/m^3)$
NILIMIT -------------- Nickel in air detection limit $(\mu g/m^3)$
CULIMIT -------------- Copper in air detection limit $(\mu g/m^3)$
ASLIMIT -------------- Arsenic in air detection limit $(\mu g/m^3)$
SELIMIT -------------- Selenium in air detection limit $(\mu g/m^3)$
CDLIMIT -------------- Cadmium in air detection limit $(\mu g/m^3)$
SNLIMIT -------------- Tin in air detection limit $(\mu g/m^3)$
SBLIMIT -------------- Antimony in air detection limit $(\mu g/m^3)$
HGLIMIT -------------- Mercury in air detection limit $(\mu g/m^3)$
PBLIMIT -------------- Lead in air detection limit $(\mu g/m^3)$
DNCODE --------------- Day or night code
COUNTER -------------- Identifies plate counter
PUMP ----------------- Identifies air sampling pump
INCTIME -------------- Time in incubator (hours)

(continued)

TABLE 51 (continued)

PC1 ------------------ Andersen stage 1 plate count
PC2 ------------------ Andersen stage 2 plate count
PC3 ------------------ Andersen stage 3 plate count
PC4 ------------------ Andersen stage 4 plate count
PC5 ------------------ Andersen stage 5 plate count
PC6 ------------------ Andersen stage 6 plate count
TOTAL PC ------------- Total MPN corrected Andersen plate count
TCONC ---------------- Total viable particle concentration (particles/m^3)
CONC ----------------- Total coliform concentration (particles/m^3)
WD ------------------- Wind direction
RH ------------------- Relative humidity (%)
TVIAB ---------------- Total aerobic bacteria in sewage (10^7 organisms/ml)
TCOLI ---------------- Total coliform in sewage (10^6 organisms/ml)
FCOLI----------------- Fecal coliform in sewage (10^5/ml)

the National Weather Service at Midway Airport, the MSD North Side Plant, and the automated on-plant (Skokie) meteorology station operated by the project staff. The Midway data provided hourly observations of temperature, humidity, wind speed and direction, and visibility. The MSD provided an on-plant measure of temperature, and the project's on-plant station collected hourly averages of temperature, humidity, solar radiation, ultraviolet radiation, and vector-averaged wind speed and direction. The Midway, MSD, and project's Skokie meteorological variables are identified as Midway, MSD, and Skokie data, respectively.

Three sources of meteorological data were used because no one source was complete. The experiences of several investigators (23,25) have indicated that meteorology plays an important role in the dispersion of viable aerosols, both in terms of which way they travel and how long they remain viable. One of the project's objectives was to develop a model to predict how viable aerosols emitted from the plant impact the surrounding community. To accomplish this, all samples must be accompanied with a complete meteorological description.

Regression analysis was carried out between the three sources to determine the applicability of the Midway data to the Skokie area. Very high correlations ($r > 0.9$ and significantly different from zero at the 0.0001 level for all three pairs of variables) were found between the hourly Skokie, MSD, and Midway temperatures. The correlations also remained high on a 24-hour basis ($r > 0.9$ and significantly different from zero at the 0.0001 level), and scatter plots of the data did not systematically deviate from a 45° angle. The order of priority for selecting a temperature to be used in the analysis was Skokie first, MSD second if Skokie was missing or invalid, and Midway third if both Skokie and MSD were missing.

The correlation between Skokie and Midway humidity was not as strong as for temperature. When compared on an hourly or 24-hour basis, the correlation coefficient was 0.62 (significantly different from zero at the 0.001 level). The reason for the difference probably could be traced to high measurement error in the Skokie record. The Midway measurement was used in the analysis when the Skokie value was missing. However, it should be recognized that this is a possible source of error.

The correlation coefficient for the wind speed measures when the Skokie wind speed was ≥ 10 was 0.62, while wind direction correlation was 0.71 when averaged on a 24-hour basis (both correlation coefficients significantly different from zero at the 0.0001 level). One important source of error between wind speed and direction measures, besides the distance between the two stations, is that the Midway data represents hourly observations while the Skokie measurements are true vector-averaged hourly averages. Although the wind speed and direction correlations are only slightly better than the humidity correlations, the errors incurred by substituting Midway data for missing Skokie data are not substantial because of a fairly complete Skokie record.

The study-period wind rose based on on-plant measurements shown in Figure 7, shows no strong predominant wind pattern. The most frequent wind

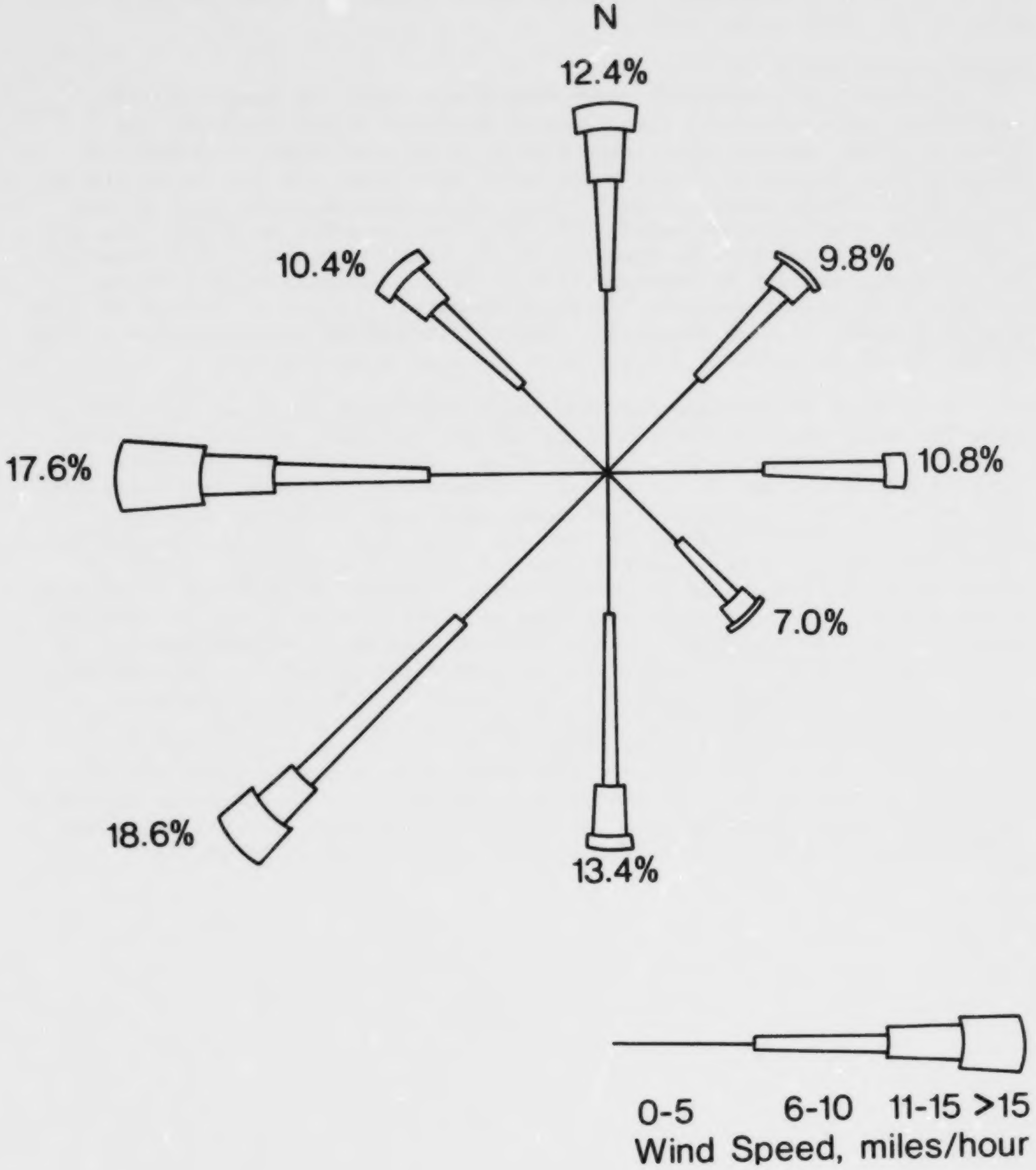

Figure 7. Study-period wind rose based on on-plant measurements.

direction was southwest for only 18.6 percent of the study period hours. The most frequent wind direction measured at Midway was south for 24.6 percent of the study period hours.

Summary of Viable Data--

Airborne measurements of total viable particles and total coliform, and sewage measurements of total aerobic bacteria, total coliform, and fecal coliform comprise the viable data sets and are shown in APPENDIX E. Sampling runs consisted of air sampling at four sites and the collection of an on-plant sewage sample. These sites, which were selected based on the previous hour's vector-averaged wind direction, were 0.8 km upwind from the plant, on the plant grounds downwind of the aeration tanks, 0.8 km downwind of the plant, and 1.6 km downwind of the plant. Sampling sites 1 through 4 (Figure 2) represent position "on-plant downwind". Sites 13 through 20 were always position "1.6 km downwind". Sites 5 through 12 were positions 0.8 km upwind or 0.8 km downwind depending on the wind direction.

A total of 72 Andersen runs for total viable particles and 26 Andersen runs for total coliform and 83 sewage samples for total aerobic, coliform, and fecal coliform bacteria were collected. Forty-eight of the viable runs were in the summer and 24 in the fall. Twenty-two of the 26 total coliform runs were in the fall. A 1-liter sewage sample was collected with each Andersen run. TABLE 52 shows the average total viable particle and average total coliform particle concentrations for the four positions. TABLE 53 shows seasonal differences for total viable particles by position. TABLE 54 shows average total viable particle and coliform concentrations by sampling location and wind direction. TABLE 55 gives average concentrations for total viable and total coliform particles summarized by median size distribution. About 70 percent appeared to be greater than 4.7 μm in diameter. On the average, 95 percent of the total viable particles discharged from the plant were greater than 2.1 μm, while 99 percent of the total coliform particles were greater than 1.1 μm. (Airborne measurements of total and fecal coliform taken with the LVAS are shown in APPENDIX F. The airborne coliphage and animal virus concentrations, measured with the LVAS, and coliphage and animal virus in sewage concentrations are presented in APPENDIX C).

TABLE 52. STUDY-PERIOD AVERAGE TOTAL VIABLE AND COLIFORM PARTICLE CONCENTRATIONS BY SAMPLING SITE POSITION

Sampling site position[a]	Total viable particles[b]		Total coliform[b]	
	Mean concentration, particles/m^3	Standard deviation, particles/m^3	Mean concentration, particles/m^3	Standard deviation, particles/m^3
0.8 km upwind	143 (62)	123	1.15 (26)	1.8
On-plant downwind	376[c] (68)	339	6.87[c] (26)	8.9
0.8 km downwind	198[c] (68)	155	1.15 (25)	2.0
1.6 km downwind	218[c] (60)	262	1.01 (24)	2.2

[a] Position relative to plant.
[b] Number of samples in ( ).
[c] Significantly greater than the upwind value ($p < 0.05$)

TABLE 53. TOTAL VIABLE PARTICLE CONCENTRATIONS BY SEASON AND SAMPLING SITE POSITION

Sampling site position[a]	Total viable particle concentrations[b], particles/m^3			
	Summer		Fall	
	Mean concentration	Standard deviation	Mean concentration	Standard deviation
0.8 km upwind	143 (38)	125	144 (24)	123
On-plant downwind	379 (43)	385	372 (25)	245
0.8 km downwind	186 (44)	152	221 (24)	161
1.6 km downwind	230 (37)	281	199 (23)	232

[a] Position relative to plant.
[b] Number of samples in ( ).

TABLE 54. STUDY-PERIOD AVERAGE TOTAL VIABLE AND COLIFORM PARTICLE CONCENTRATIONS BY SAMPLING SITE AND WIND DIRECTION

Sampling site	Distance from plant, km	Downwind concentrations, particles/m^3		Upwind concentrations, particles/m^3	
		Total viable particles	Coliform	Total viable particles	Coliform
1	---	447 (12)[a]	3.96 (7)		
2	---	381 (21)	3.42 (12)		
3	---	347 (21)	17.08 (5)		
4	---	354 (13)	12.20 (2)		
5	0.8	268 (6)	1.10 (6)	59 (7)	0.37 (3)
6	0.8	191 (8)	2.60 (3)	157 (10)	
7	0.8	155 (14)	1.20 (9)	135 (12)	0.00 (2)
8	0.8	199 (7)	1.10 (2)	378 (3)	
9	0.8	294 (7)	0.37 (3)	227 (5)	0.94 (7)
10	0.8	93 (9)		161 (6)	0.37 (3)
11	0.8	228 (13)	0.00 (12)	118 (16)	1.97 (9)
12	0.8	232 (4)		54 (3)	1.65 (2)
13	1.6	169 (6)	2.03 (6)		
14	1.6	580 (9)	0.73 (3)		
15	1.6	200 (10)	1.10 (8)		
16	1.6	60 (6)	0.00 (2)		
17	1.6	174 (6)	0.00 (3)		
18	1.6	248 (8)			
19	1.6	171 (12)	0.55 (2)		
20	1.6	144 (3)			

[a] Number of samples in ( ).

TABLE 55. MEDIAN SIZE DISTRIBUTIONS FOR TOTAL VIABLE PARTICLES AND TOTAL COLIFORM BASED ON ALL SAMPLES

Stage	Diameter µm	Total viable particles		Total coliform	
		TVP/m^3	%	Coliform/m^3	%
1	>7	103	43	1.28	50
2	4.7 - 7	54	23	0.65	25
3	3.3 - 4.7	43	18	0.40	16
4	2.1 - 3.3	18	8	0.13	5
5	1.1 - 2.1	13	6	0.08	3
6	0.65- 1.1	5	2	0.02	1
Total		236	100	2.56	100

Average sewage concentrations by month and for the 8-month study period are shown in TABLE 56. Total aerobic bacteria concentrations are reported as 10^7 organisms per 100 ml, total coliform as 10^6 organisms per 100 ml, and fecal coliform as 10^5 organisms per 100 ml.

Summary of Non-Viable Data--

A total of 20 non-viable air pollutants were monitored during the study period, five gases (SO_2, NO_2, Cl_2, NH_3, H_2S) and 15 associated with suspended particulate matter (TSP, $SO_4^=$ NO_3^-, V, Cr, Mn, Ni, Cu, As, Cd, Se, Sn, Sb, Hg, and Pb). Grab samples of aeration tank liquids were taken concurrently with air measurements and analyzed for 12 pollutants ($SO_4^=$, NO_3^-, V, Ni, Cu, As, Se, Cd, Sn, Sb, Hg, and Pb). The measurements appear in APPENDIX E. Sampling was carried out every 5 days from April 4 to November 30. Air samples for all 20 parameters were collected at the plant for every collection period. Of the remaining four sites, two were used to collect TSP, $SO_4^=$, and NO_3^- while two were used to collect samples of the five gases and 12 metals. TABLE 57 shows the total number of days each air pollutant was sampled, the number of days when zero, one, two, and three samples were above the detection limit, the total number of samples above the detection limit, and the average detection limit of each measurement procedure. This table shows that 10 out of the 20 non-viable indices were below the detection limit on over half of the sampling days. Only seven of the 20 indices were above the detection limit at one or more locations on every measurement day.

TABLES 58 through 60 show the particulate and gas data averaged by location for the study period. The maximum average assumes all concentrations below the detection limit are equal to the detection limit. The minimum average assumes all concentrations below the detection limit are equal to zero.

TABLE 56. SUMMARY OF VIABLE SEWAGE DATA

Averaging period 1977	Total aerobic bacteria (10^7/100 ml)			Total coliform (10^6/100 ml)			Fecal coliform (10^5/100 ml)		
	No. of samples	Mean	Standard deviation	No. of samples	Mean	Standard deviation	No. of samples	Mean	Standard deviation
April	6	155	96	6	37	16	6	35	32
May	10	525	1,323	10	65	109	10	67	67
June	11	20	19	11	19	12	11	40	29
July	11	59	54	11	26	24	11	58	34
August	5[a]	889	1,789	11	104	85	11	128	59
September	10[b]	30	40	11	70	44	11	120	52
October	10	40	21	10	64	30	10	73	36
November	13	39	24	13	42	25	13	79	59
April-November	78	165	659	83	54	59	83	78	56

[a] Plus one sample of > 10^7/100 ml. Five samples were > 10^9/100 ml.
[b] Plus one sample of < 10^9/100 ml.

TABLE 57. NON-VIABLE DETECTION LIMIT SUMMARY

Non-viable constituent	No. of sampling days	No. of days no samples> det. limit	No. of days 1 sample > det. limit	No. of days 2 samples > det. limit	No. of days 3 samples> det. limit	Total samples > det. limit	Detection limit ($\mu g/m^3$)
NH_3	15	10	1	3	1	10	2.29
Cl_2	34	0	3	12	19	84	2.12
H_2S	28	26	1	1	0	3	0.70
NO_2	41	0	4	16	21	99	7.60
SO_2	41	17	6	12	6	48	3.30
TSP	47	0	0	2	45	142	1.00
$SO_4^=$	47	6	0	20	21	103	0.01
NO_3^-	47	6	0	8	33	115	0.01
V	32	14	4	4	10	42	0.002
Cr	32	29	3	0	0	3	0.022
Mn	32	8	5	8	11	54	0.022
Ni	32	29	3	0	0	3	0.009
Cu	32	0	0	5	27	91	0.009
As	32	29	1	2	0	5	0.011
Cd	32	19	9	4	0	17	0.009
Se	32	18	9	3	2	21	0.007
Sn	32	19	10	1	2	18	0.011
Sb	32	25	4	2	1	11	0.011
Hg	32	25	4	3	0	10	0.009
Pb	32	0	0	4	28	92	0.018

TABLE 58. STUDY-PERIOD AVERAGE AMBIENT TRACE ELEMENT CONCENTRATIONS BY SITE

Sampling site[a]	Concentration[b], µg/m^3											
	V		Cr		Mn		Ni		Cu		As	
	Average max.[c]	Average min.[d]	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.	Average max.	Average min	Average max.	Average min.
A	0.0045	0.0021	0.0318	0.0000	0.0417	0.0292	0.0118	0.0003	0.2141	0.2141	0.0109	0.0012
B	0.0041	0.0014	0.0277	0.0000	0.0361	0.0183	0.0100	0.0000	0.3691	0.3691	0.0086	0.0000
C	0.0043	0.0019	0.0327	0.0058	0.0478	0.0380	0.0115	0.0006	0.4247	0.4247	0.0099	0.0007
D	0.0040	0.0017	0.0287	0.0000	0.0459	0.0376	0.0106	0.0006	0.3971	0.3971	0.0100	0.0019
E	0.0073	0.0047	0.0385	0.0118	0.0363	0.0262	0.0104	0.0000	0.3123	0.3123	0.0093	0.0000

Sampling site	Concentration[b], µg/m^3											
	Se		Cd		Sn		Sb		Hg		Pb	
	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.
A	0.0090	0.0025	0.0157	0.0042	0.0124	0.0037	0.0120	0.0018	0.0134	0.0015	0.6083	0.6083
B	0.0081	0.0029	0.0131	0.0000	0.0111	0.0021	0.0122	0.0032	0.0112	0.0021	0.7412	0.7412
C	0.0084	0.0017	0.0149	0.0018	0.0117	0.0022	0.0114	0.0000	0.0129	0.0013	0.8400	0.8400
D	0.0074	0.0021	0.0148	0.0033	0.0115	0.0022	0.0114	0.0018	0.0126	0.0026	0.6455	0.6455
E	0.0086	0.0041	0.0170	0.0069	0.0109	0.0022	0.0117	0.0024	0.0116	0.0000	0.8394	0.8394

[a] See TABLE 12 for key to sampling sites.

[b] Determined from Whatman 541 filters analyzed by energy dispersive X-ray fluorescence spectrometry.

[c] Average maximum assumes all concentrations below the detection limit are equal to the detection limit.

[d] Average minimum assumes all concentrations below the detection limit are equal to zero.

TABLE 59. STUDY-PERIOD AVERAGE GAS CONCENTRATIONS BY SITE

Sampling site[a]	Concentration, $\mu g/m^3$									
	Cl_2		NH_3		NO_2		H_2S		SO_2	
	Average max.[b]	Average min.[c]	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.	Average max.	Average min.
A	13.55	11.05	2.90	0.36	46.39	42.72	0.88	0.11	10.49	3.27
B	15.25	11.80	2.96	0.43	53.59	47.32	0.72	0.00	13.98	7.22
C	13.39	11.03	2.47	0.17	60.57	57.01	0.97	0.22	13.68	7.08
D	16.73	13.59	2.76	0.57	54.85	54.85	1.06	0.27	15.80	8.76
E	14.81	11.42	2.66	0.25	53.83	53.49	0.73	0.00	8.76	3.11

[a] See TABLE 12 for sites key.

[b] Average maximum assumes all concentrations below the detection limit are equal to the detection limit.

[c] Average minimum assumes all concentrations below the detection limit are equal to zero.

TABLE 60. STUDY-PERIOD AVERAGE AMBIENT TSP, NITRATE, AND SULFATE CONCENTRATIONS BY SITE

Sampling site[a]	Average ambient concentration[b], µg/m^3		
	TSP	NO_3^-	$SO_4^=$
A	77.56	1.60	14.08
B	74.47	1.40	11.31
C	87.45	1.46	13.43
D	82.21	1.57	13.03
E	68.13	1.44	12.04

[a] See TABLE 12 for key to sampling sites.
[b] Determined from glass-fiber filters.

TABLE 61. MEAN TOTAL SUSPENDED PARTICULATE SIZE DISTRIBUTION (PLANT SITE)

Stage	Diameter, µm	Average concentration[a], µg/m^3	Weight %
1	> 7.0	21.0	28.7
2	3.3-7.0	15.0	20.6
3	2.0-3.3	9.8	13.4
4	1.1-2.0	10.7	14.8
5	0.01-1.1	16.3	22.5
Total		72.8	100.0

[a] Based on 17 samples.

The actual concentration falls between these averages. All concentrations are in $\mu g/m^3$. A summary of TSP particle size distribution (based on plant site measurements) is given in TABLE 61. About 50 percent (by weight) were greater than 3.3 μm. A summary of non-viable sewage data is shown in TABLE 62. Number of samples, detection limits, study period average concentrations, and standard deviations of all 12 pollutants measured are included.

Summary of Plant Operation Data--

The plant operation data, collected by the MSD, included daily flow rates and analytical data describing sewage quality. All flows represented daily totals in million gallons per day. All analytical data were in mg/liter.

Variables relating to the plant as a whole included rain in inches, total sewage, total air corrected to 590°F at 21.9 p.s.i., air temperature and air pressure at the aeration galleries. Sludge is sent to the concentration tank before being shipped to the West Southwest Plant. The difference between the total flow to the concentration tank and total flow to the West Southwest Plant is sent back for treatment to the preliminary tanks. Flow to the concentration tank from the preliminary tanks, flow to the concentration tank from the settling tank, and flow from the concentration tank to the West Southwest Plant were included in the data set. The percent solids and tons of dry solids per day in the flow to the West Southwest Plant were also included. Chlorination data included in the operating data set were dosage in ppm, residual in outfall, and total NaOCl used per day.

Twenty-four-hour composite samples of total sewage treated, total return sludge, and percent solids for each battery are recorded for each aeration tank battery. The difference between the total sewage treated and return sludge is the total new sewage treated per day for each battery.

The remaining variables were all analytical measures of sewage quality throughout the plant: measures of organic and ammonia nitrogen, dissolved oxygen, 5-day biological oxygen demand, and suspended solids (fixed and volatile) in the incoming sewage; measures of organic and ammonia nitrogen, 5-day biological oxygen demand, and suspended solids (fixed and volatile) taken from the sewage as it leaves the preliminary tanks and enters the aeration tanks (considered the best description of the sewage in the aeration tanks); final effluent measures of organic and ammonia nitrogen, dissolved oxygen, 5-day BOD, total suspended solids, and temperature; and nitrite and nitrate.

An analysis of the plant operation data set showed that the flows of total sewage and air varied by a factor of two throughout the study period. It is interesting to note that the ratio of total sewage to air varies by over a factor of three, implying that there is no constant operating condition for this ratio.

Development of Personal Exposure Indices

Two viable and nine non-viable pollutants were selected for the model to predict personal exposure indices for use in the health analysis. The main criterion used in selecting these indices was the ability to reliably

TABLE 62. SUMMARY OF NON-VIABLE SEWAGE DATA

Constituent	No. of samples	No. of samples above detection limit	Detection limit µg/liter	Study period ave. conc. µg/liter	Standard deviation µg/liter
$\text{SO}_4^=$	27	27	0.1	26.6[a]	17.0[a]
NO_3	27	27	0.1	7.6[a]	4.6[a]
V	19	0	12	b	b
Ni	19	19	2	215	54
Cu	19	19	2	218	251
As	19	19	60	171	69
Se	19	0	2	b	b
Cd	19	19	3	129	56
Sn	19	19	1	60	15
Sb	19	10	1	1.4[c]	1.9[c]
Hg	19	0	4	b	b
Pb	19	19	5	280	141

[a] Concentrations in mg/liter.

[b] All samples below detection limit.

[c] Samples below detection limit averaged as 0 µg/liter.

measure the pollutant. In the case of fecal coliforms and many of the metals, the study area concentrations were close to, or below, detection limits.

Viable Exposure Indices--

The two viable indices selected for this analysis were total viable particles and total coliform particles. Total viable particles were reliably measured throughout the study period. Although total coliform concentrations were very close to the sampler's detection limit, the relatively large number of samples collected were combined to minimize the uncertainties of each measurement.

Samples for total viable particles and coliform were collected at 20 sites that were either directly upwind or downwind of the plant. The upwind and downwind average concentrations of total viable particles and total coliform by sampling sites were summarized in TABLE 54. Figures 8 and 9 show these data projected over the entire study area. These maps were generated using the SYMAP program. This program uses an inverse square weighting scheme to interpolate concentration at every point within the study area from the concentration at the 20 sampling locations. It was judged to be the best model available because it integrates all meteorological and topographical conditions by using all the air pollution data to interpolate concentrations in the study area. A comparison of the downwind maps to the upwind maps identifies the plant as a source of total viable and total coliform particles within certain portions of the study area. The downwind total viable particle map also identifies a second source of total viable particles near site 14. This source does not emit coliform particles.

Exposure indices for total viable particles and total coliform were developed by combining the modeled upwind and downwind concentrations with the study-period wind rose data shown in Figure 7. The process used to accomplish this is as follows: First, for each household in the study area, an upwind and a downwind exposure index were predicted by SYMAP. Each household was then associated with the closest wind direction of Figure 7. The percentage of the time each household was upwind and downwind of the plant was calculated by assuming that each house is downwind from the plant if the wind is within a 135° arc directly across the study area from that house. For example, if a household has been associated with the northwest direction, winds from the east, southeast, and south place that house downwind of the plant. Winds from the southwest, west, northwest, north and northeast place that house upwind of the plant. The house is, therefore, downwind of the plant 10.75% + 7.04% + 13.39% or 31.8 percent of the study period and upwind 18.62% + 17.55% + 10.42% + 12.40% + 9.76% or 68.75 percent of the study period.

The exposure index for each household is then calculated from Equation 1:

$$\text{Exposure} = (\text{UPEXP})\ (\%\ \text{upwind}) + (\text{DOWNEXP})\ (\%\ \text{downwind})$$

Where: Exposure = household exposure index for study period

UPEXP = household upwind exposure

% upwind = percent of study period house was upwind of the plant

DOWNEXP = household downwind exposure

% downwind = percent of study period house was downwind of the plant

UPEXP and DOWNEXP are predicted by SYMAP for each household used in the analysis.

Two studies were carried out to check the accuracy of the process described above. First, the study-period wind direction distribution was compared to the wind direction distribution for sampling hours only. These two distributions were almost identical. This allows the combination of study-period wind data and exposure indices with no error resulting from possible abnormal winds during sampling.

Second, a validation of SYMAP's interpolation accuracy was carried out. This was accomplished by dropping one of sites 5 through 12 at a time and having SYMAP predict a concentration at the missing site. This represents a worst-case analysis because at no point in the study area does SYMAP have to search further for sampling sites than from one of sites 5 to 12 to the surrounding sampling points. The comparison between the actual and predicted concentration at sites 5 through 12 showed that SYMAP always interpolated an exposure index to at least within a factor of two under worst-case conditions. This is further confirmed by examining maps of downwind exposure when one of the 0.8-km downwind data sites was missing. These maps all showed the same pattern of elevated exposures into the community as is shown in Figure 8.

In addition to the study-period-averaged exposure indices for total viable particles and total coliform, an exposure index for every 2-week Health Watch period for total viable particles was calculated. Total coliform was not used in the 2-week analysis because the data were all collected in the fall. In addition, the accuracy of combining subgroups of the data when the measurement is so close to the detection limit would be questionable. The process of developing 2-week exposure indices was the same as the study-period index. For each 2-week period, an upwind and downwind exposure index was calculated for each household. These indices were then combined with a wind direction distribution from the same 2-week period using Equation 1. This resulted in 16 exposure indices for each household in the study. The SYMAP modeling technique for the 2-week periods differed slightly from that used for the overall study period. Details are given in APPENDIX G.

Non-Viable Exposure Indices--

Nine of the 20 non-viable pollutants included in the environmental monitoring effort were selected to become personal exposure indices. The criteria used to select these variables were that the pollutant concentration must be above the sampling method's detection limit a majority of the time, and that there must be some variation across the study area. The identification of the plant as a source was not a factor here, because, with the

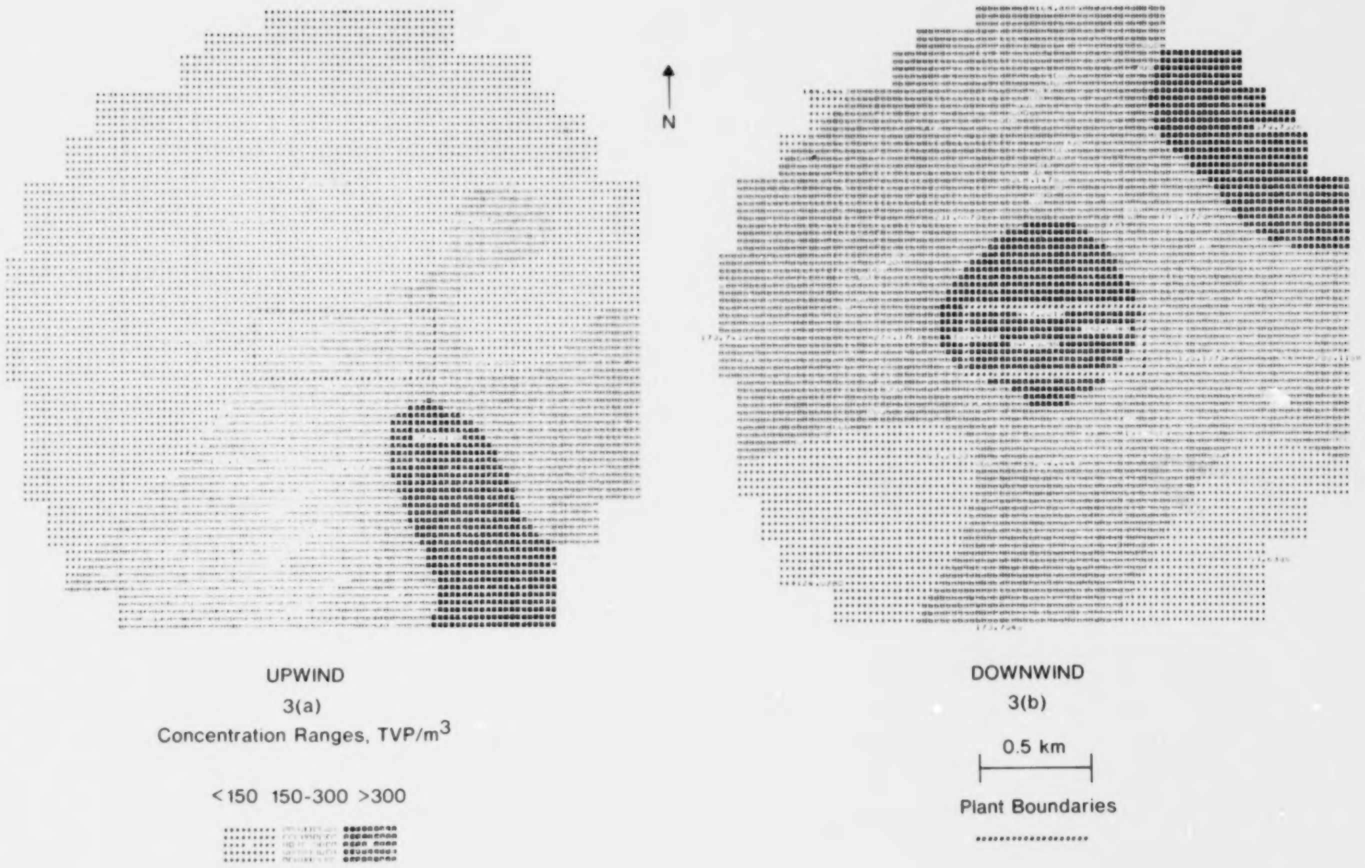

Figure 8. Study area concentration profiles for total viable particles.

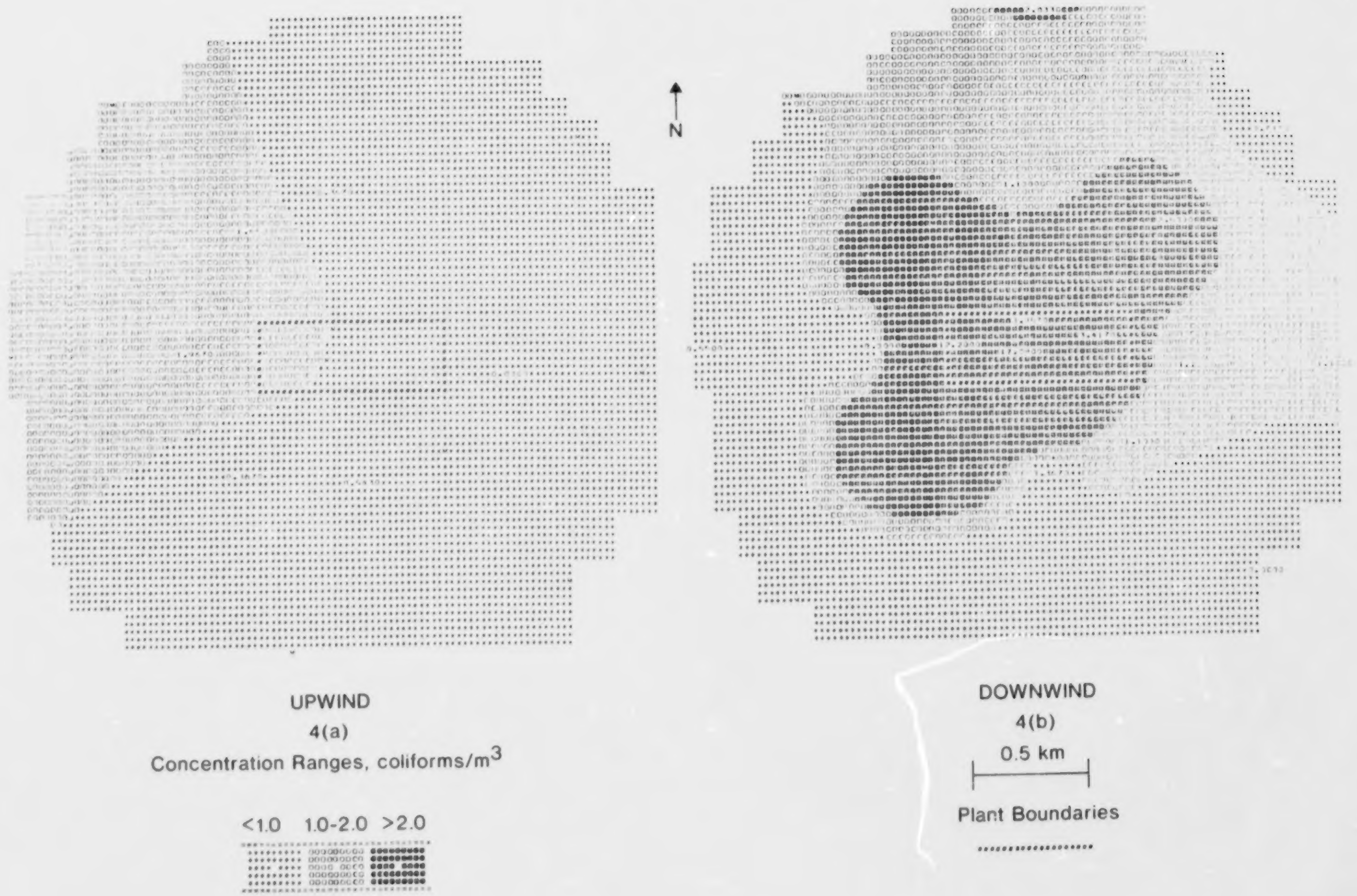

Figure 9. Study area concentration profiles for total coliform particles.

possible exception of tin, none of the non-viable indices could be linked back to the plant.

The following nine indices were developed into personal exposure indices. Figures 10 through 18 show the study-period concentration profile of the pollutants. A short description of the characteristics of each pollutant is included with each index.

1) NO_2 - No source of NO_2 could be identified in the study area. Overall, the plant appears to be a little cleaner than the study area. Summer concentrations were higher than fall concentrations.
2) SO_2 - No source of SO_2 could be identified in the study area. No consistent seasonal pattern was observed.
3) TSP - The major source of TSP in the area is Chicago. Wind direction analysis also identifies the Tunnel and Reservoir Project (TARP) construction site as a possible source of particulates. The treatment plant is not a source. Summer concentrations were higher than fall concentrations.
4) NO_3^- - Chicago is the only major source of nitrates in the study area. The plant might possibly be a source during west winds but the range is only 1.4 to 1.6 $\mu g/m^3$. No seasonal pattern is evident.
5) $SO_4^=$ - Chicago is the only source of sulfates in the area. Summer averages are higher than fall averages.
6) Vanadium - Wind direction identifies a source southwest of the study area. The TARP site is also a possible source. Summer concentrations are higher than fall concentrations.
7) Manganese - Chicago appears to be the main source of Mn in the study area. The TARP construction site is also a possible source. Fall concentrations of Mn are higher than summer concentrations.
8) Copper - Wind direction analysis identifies a source northeast of the study area. No seasonal differences were evident.
9) Lead - Chicago is the only major source of lead in the study area. The wind direction analysis also identifies a possible source west of the study area. The TARP construction site also appears to be a Pb source. No seasonal differences were evident.

Of the remaining variables, NH_3, H_2S, Cr, Ni, As, Se, Cd, Sb, Hg, and Sn were not included in the health analysis because the number of samples above the detection limit was less than 21. Cl_2 was not included because the range across the study area was only 11.03 to 11.80 $\mu g/m^3$

The calculation of household exposure indices for the nine non-viable pollutants was much more direct than for the viable measurements. Figures 10 to 18 represent study-period averages of the non-viable indices integrated for all wind directions. It was, therefore, only necessary for SYMAP to interpolate an exposure index for each household in the health study for each pollutant.

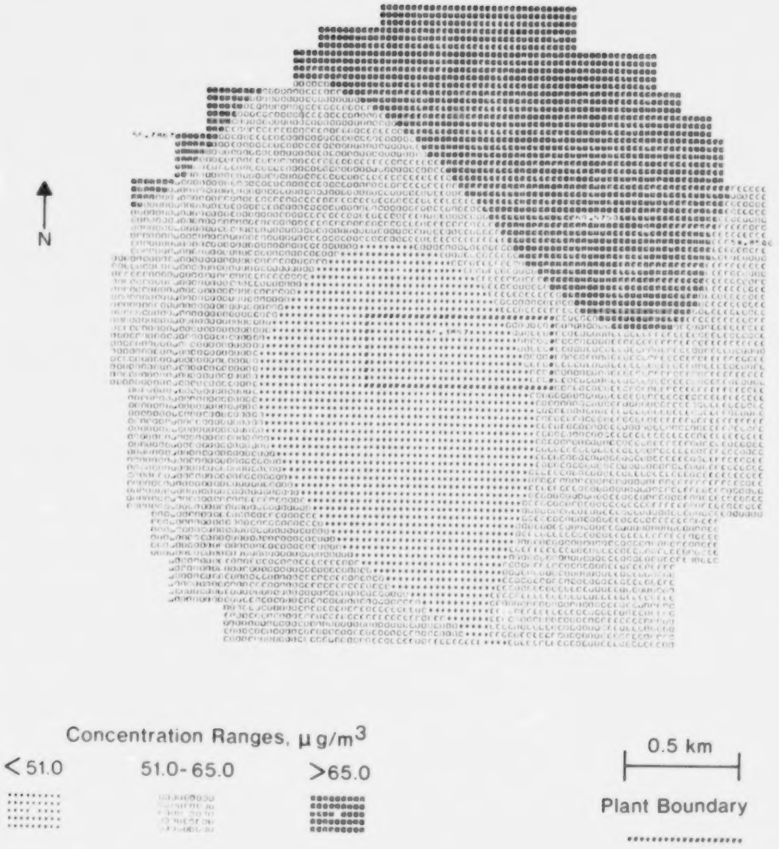

Figure 10. Study area concentration profile for nitrogen dioxide.

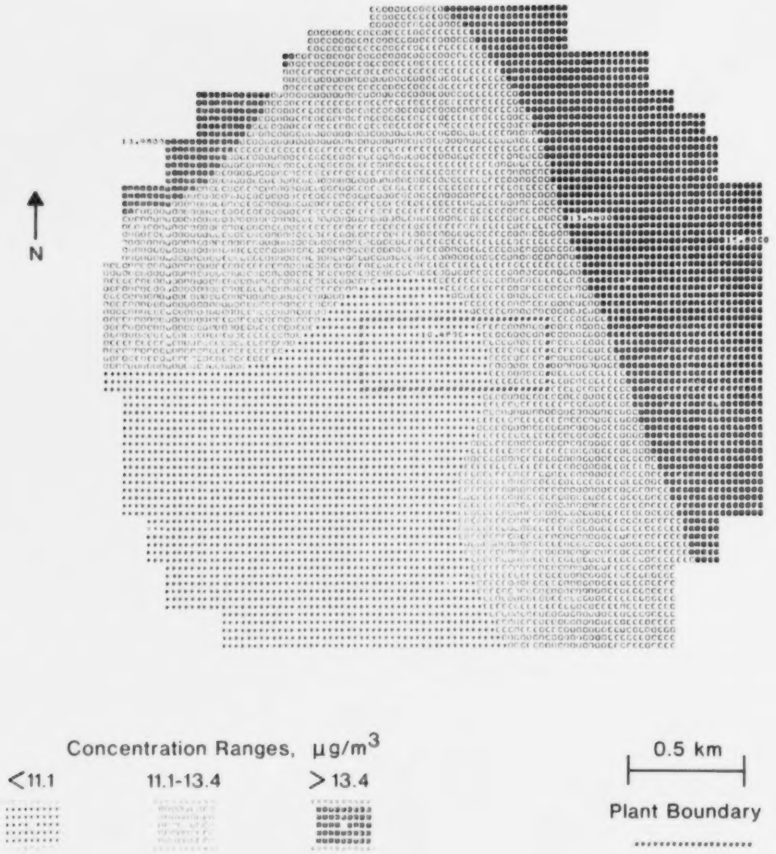

Figure 11. Study area concentration profile for sulfur dioxide.

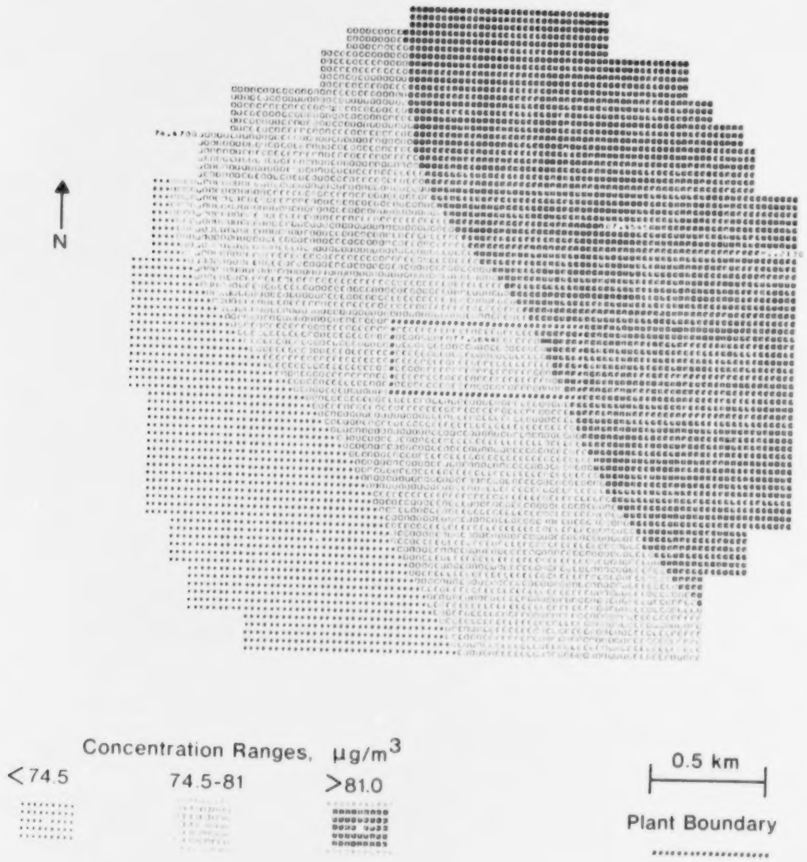

Figure 12. Study area concentration profile for total suspended particulates.

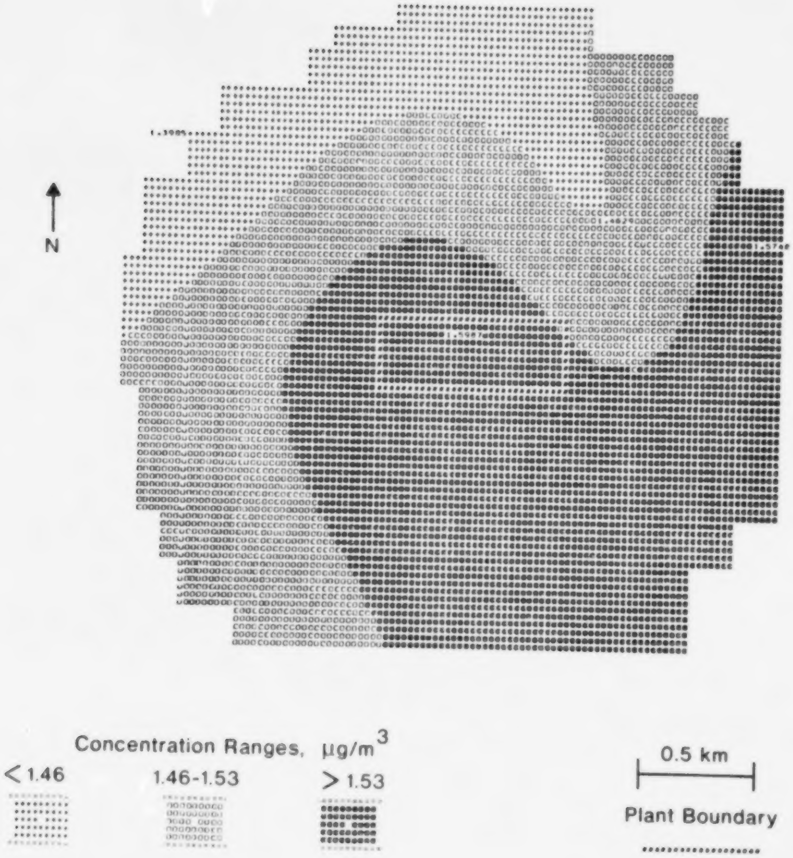

Figure 13. Study area concentration profile for airborne nitrates.

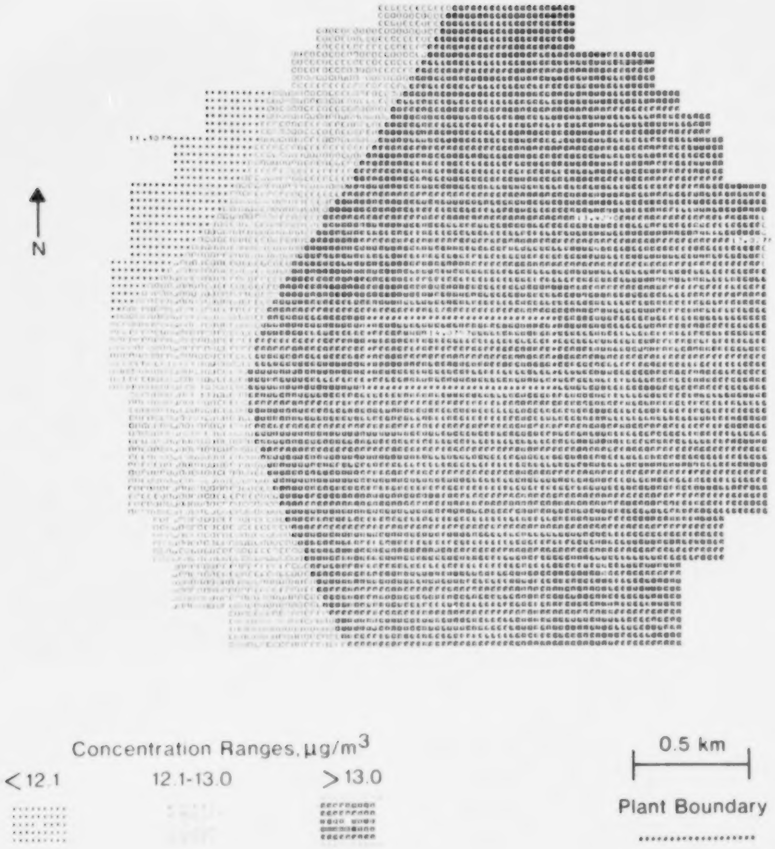

Figure 14. Study area concentration profile for airborne sulfates.

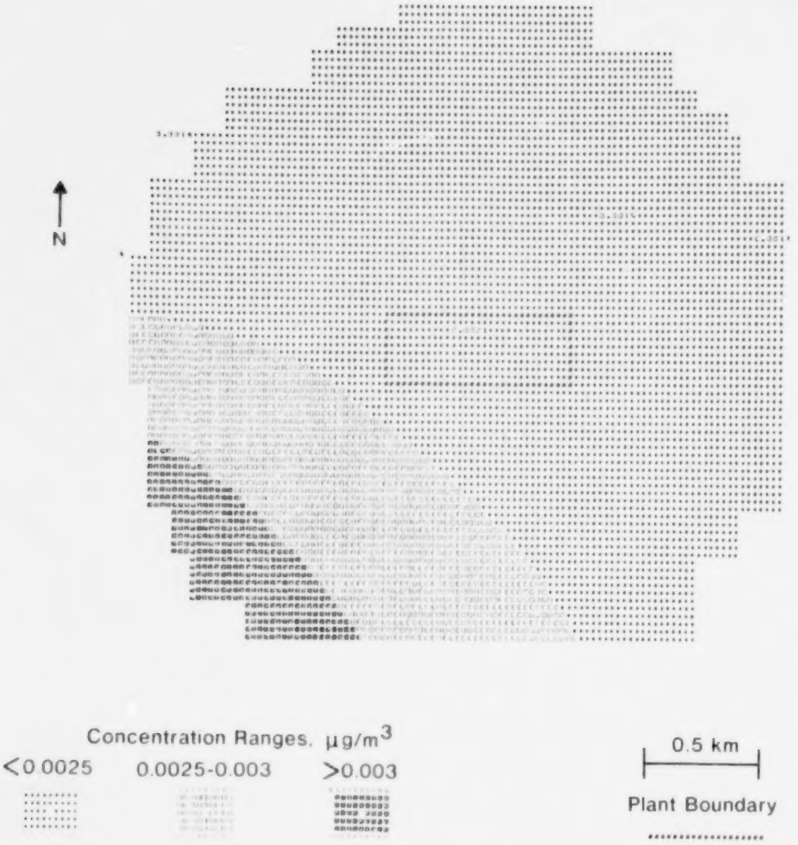

Figure 15. Study area concentration profile for airborne vanadium.

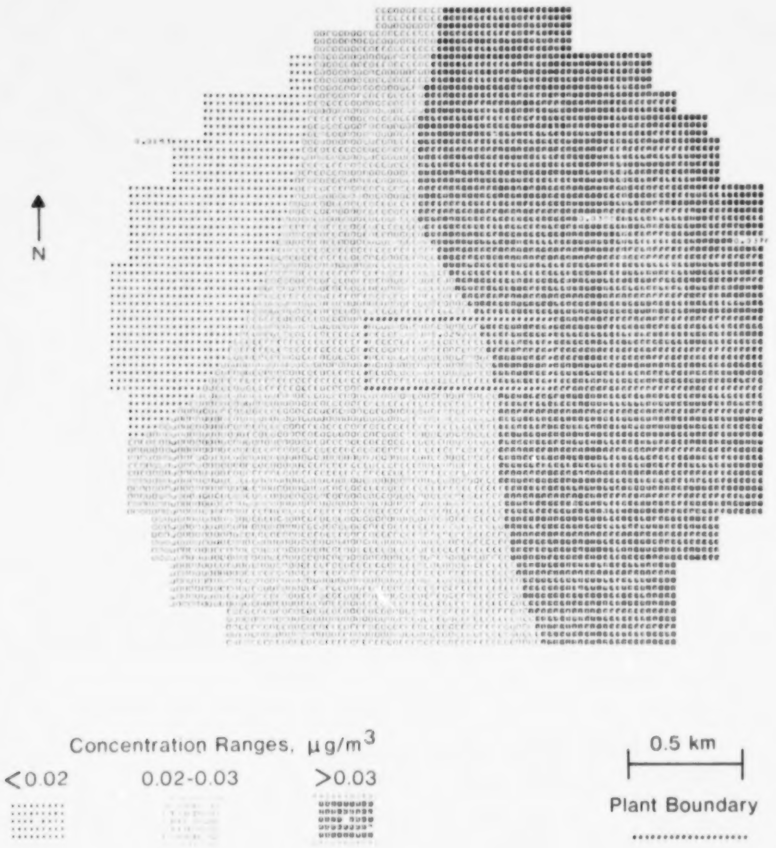

Figure 16. Study area concentration profile for airborne manganese.

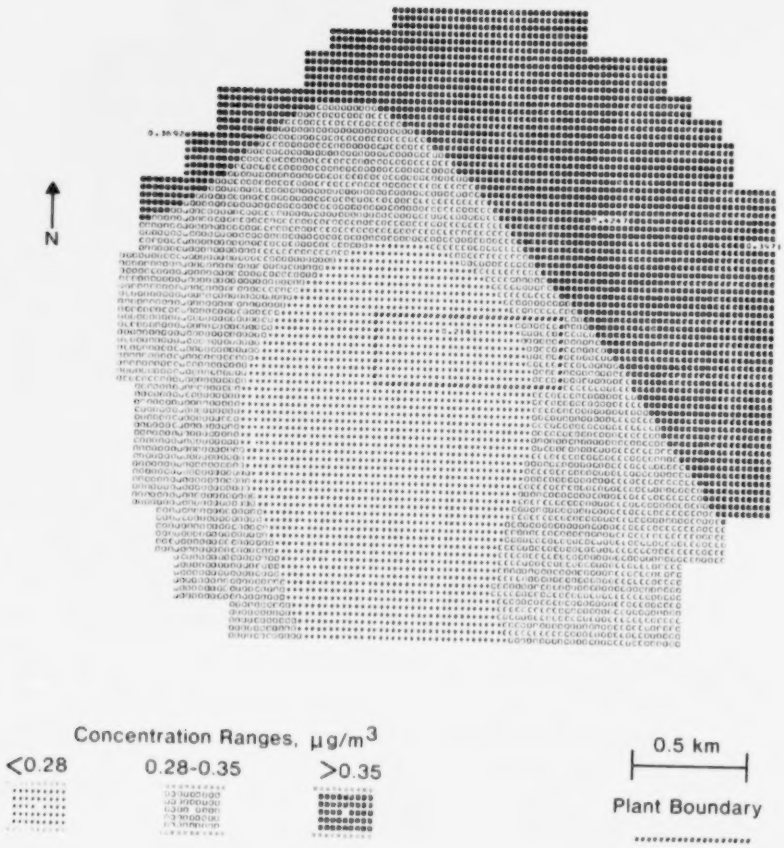

Figure 17. Study area concentration profile for airborne copper.

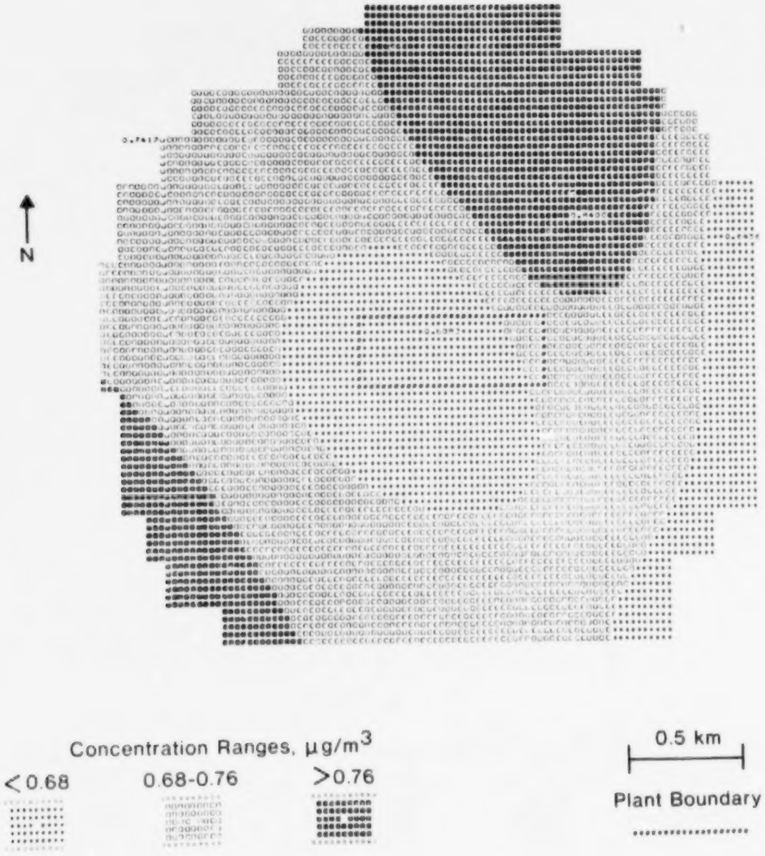

Figure 18. Study area concentration profile for airborne lead.

It is important to point out that all non-viable concentrations measured, with the exception of $SO_4^=$, were very low with respect to environmental health standards and Chicago averages for the same seasons. Chicago sulfate data were not available, so no comparison could be carried out.

Analysis of Plant as an Emission Source

Distance-Concentration Relationships--

All 20 non-viable and two viable pollution indices were modeled by SYMAP to identify which pollutants could be related back to the sewage treatment plant as an identifiable source. For the viable indices, upwind and downwind maps were plotted (Figures 8 and 9). For the non-viable indices, integrated wind direction maps as well as maps sorted by wind direction were plotted. Of all 22 indices, only total viable particles (Figure 8), total coliform particles (Figure 9), and possibly tin (Figure 19) identify the plant as a source.

The total viable particle average concentrations show a decrease with distance from the plant. TABLE 52 shows that the plant downwind total viable particle concentration is greater than three times the upwind or background concentration. At 0.8 km downwind of the plant, the average total viable particle concentration is still 45 percent greater than the background concentration. The 1.6 km-downwind average concentration is also higher than the background concentration.

The total viable particle upwind and downwind maps, Figure 8, show that the plant contribution to the total viable particle air concentration extends further than 0.8 km downwind of the plant. The 1.6-km downwind concentration is higher than the 0.8-km downwind concentration, however, this is partially the result of some other source or sources of total viable particles located near site 14 (Figure 4). Such a source or sources located near site 14 not only increase the downwind concentration at site 14 but also increase the 0.8-km upwind concentration at site 6. Removing site 14 and site 6 upwind from the analysis removes any complications encountered because of the other possible sources at site 14. The remaining sites show a clear pattern of the effect of the treatment plant on the surrounding community when they are downwind of the facility (Figure 20).

An inventory of industrial and municipal facilities in the entire study area was conducted during the study period. No obvious source of viable organisms was noted. The Metropolitan Sanitary District does maintain a consumer pick-up station for "Nu-earth", treated sewage sludge for home garden use, directly north of the plant. However, this operation is considered to be too small and too distant from site 14 to have an effect on total viable particle concentration. The road into site 14 is not paved, although it is heavily used, and accumulation of rain water was noted to occur in pockets of gravel and mud. The roads in the area surrounding all other sampling points are paved.

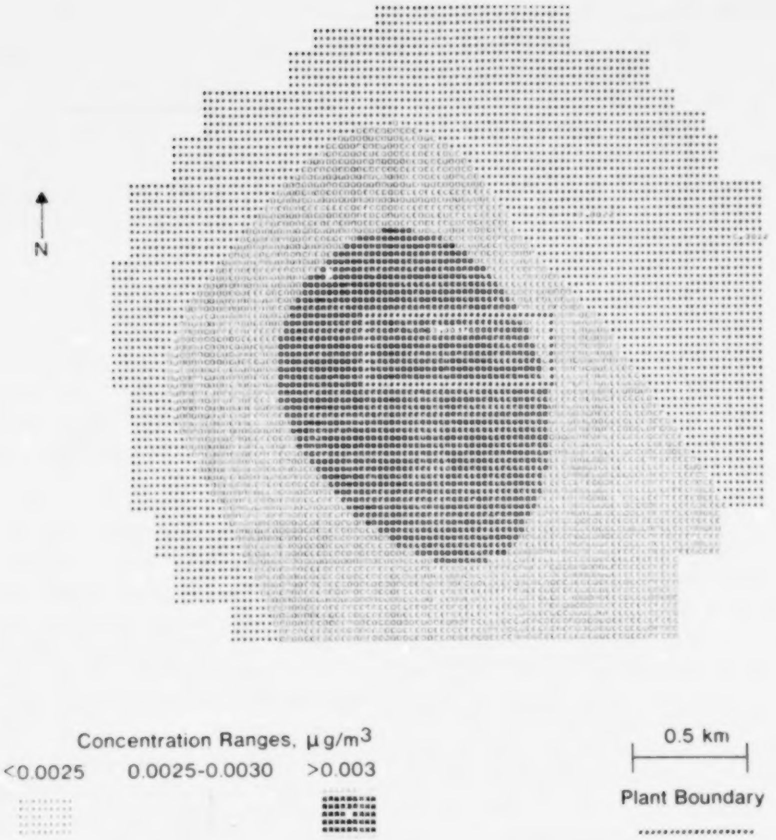

Figure 19. Study area concentration profile for airborne tin.

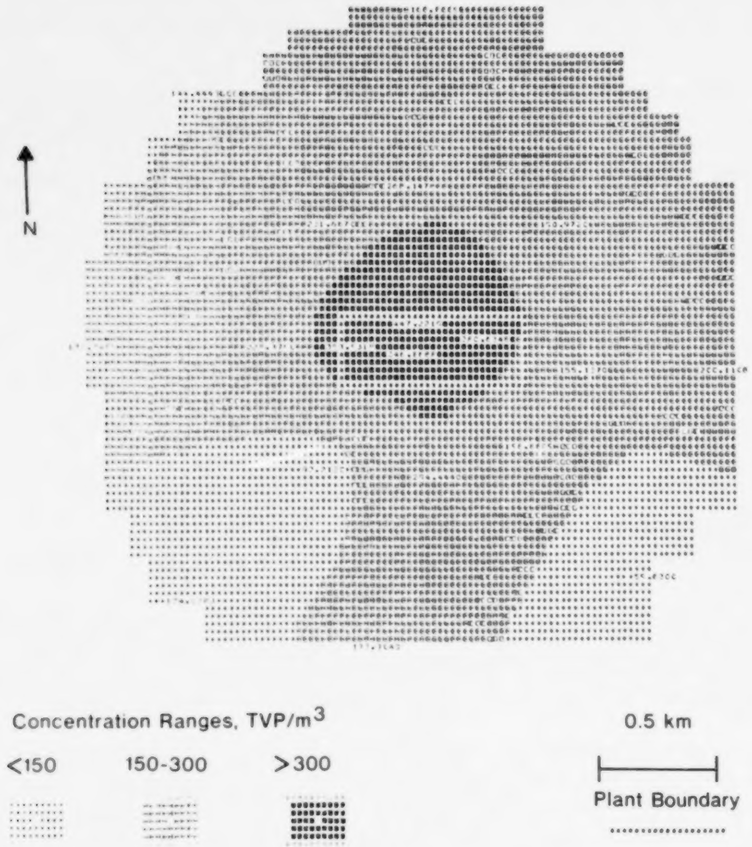

Figure 20. Study area concentration profile for total viable particles, excluding site 14: downwind.

TABLE 63 shows the four averaged position variables without samples collected at site 6 (when it was upwind of the plant) and site 14. The downwind concentrations are all higher than background and decrease with distance from the plant. Figure 20 shows the downwind study area concentrations affected by the plant source only and supports this conclusion.

TABLE 63. AVERAGE TOTAL VIABLE PARTICLE CONCENTRATIONS BY SAMPLING POSITION WITHOUT SITES 6 UPWIND AND 14 DOWNWIND

Sampling site position[a]	Total viable particles		
	No. of samples	Mean concentration (particles/m^3)	Standard deviation (particles/m^3)
0.8km upwind	52	141	121
On-plant downwind	68	376[b]	339
0.8km downwind	68	198[b]	155
1.6km downwind	51	155	144

[a] Position relative to plant.
[b] Significantly greater than the upwind value ($p < 0.05$).

A one-way analysis-of-variance was run to test the significance of the difference between the means of the four position variables. When run both with and without sites 6 upwind and 14 downwind, the difference between position means is significant at the 0.05 significance level.

In order to determine which of the three downwind position means are significantly higher than background, t-tests were run comparing the 0.8-km upwind concentration to the plant, 0.8 and 1.6-km downwind concentrations separately. These tests were run both with and without sites 6 upwind and 14 downwind. When all 20 downwind and eight upwind sites are included, the differences in concentration between 0.8-km upwind and all three downwind sites are significant at the 0.05 level. The same comparisons when run on the data without sites 6 upwind and 14 downwind show that the plant and 0.8-km downwind are significantly higher than background at the 0.05 significance level. The 1.6-km downwind concentration is not significantly higher than the 0.8-km upwind concentration at the 0.05 or 0.1 significance levels.

The total coliform concentration at the plant is six times greater than any of the other position concentrations (TABLE 52). Assuming the 0.8-km upwind represents background conditions, it appears that the plant does add significant amounts of coliform to the air that passes over it. By the time the air reaches 0.8 km downwind of the plant, however, the coliform concentration returns to the background levels. The plots of the upwind and downwind coliform concentrations (Figure 9) confirm this. A one-way analysis-of-variance showed the variation in means of the coliform data to be significant at the 0.05 significance level.

The study area concentrations of tin are shown in Figure 19. This map represents only 18 measurements collected during the study period. Because of the small number of samples above the detection limit, no wind direction analysis of tin was possible. For this reason, the identification of the plant as a source of tin is quite tentative.

The following conclusions appear to be warranted: 1) the effect of the plant on total viable particles is significant out to at least 0.8 km downwind and does not return to background until almost 1.6 km downwind; 2) the effect of the plant on total coliform concentration is significant. However, because of the limited viability of coliform in air, the concentration returns to background <0.8 km downwind from the plant.

In order to thoroughly compare the differences between the means from all four positions, the Duncan multiple range test in conjunction with a one-way analysis-of-variance was used. The Duncan tests show when sites 6 upwind and 14 downwind are not included, that the plant measurements of total viable particles and total coliform are significantly higher than the other three position means at the 0.05 level of significance. Log transformations are commonly used for air pollution data because of extreme values. When the natural log of the concentration of total viable particles is used, the Duncan test shows that the plant concentration is higher than the other three position concentrations and that the 0.8-km downwind concentration is higher than background at the 0.05 significance level.

Meteorology, Plant Operating Characteristics and Concentrations--

A second approach to the characterization of the plant as an emission source was a comparison between air quality measurements and sewage characteristics, meteorology, plant operating parameters, and interaction effects between these variables. The goal of this analysis was to develop a model to predict viable concentration in the study area based on meteorology, sewage characteristics and plant operating conditions. A second goal was to determine if the plant was a significant source of any non-viable pollution. When on-plant total viable particle concentrations were compared using regression analysis with plant operating characteristics (such as sewage throughput or air rate), or total aerobic bacteria in sewage concentrations, no obvious relationships were found. However, sampling locations 1-4 (Figure 2) were not always directly downwind. When the analysis is limited to those observations ± 22.5° from due east or west (sites 2 and 4), a rough association ($r = 0.68$, significantly different from zero at the 0.005 level) is evident (Figure 21). These concentrations reflect air passage across maximum tank surface areas. (The north-south distance is only 25 percent of that from east to west.) The spread in the data could not be further explained by systematic differences in wind speed, temperature, or relative humidity. Total coliform also did not show any striking relationships with sewage concentrations or operating parameters.

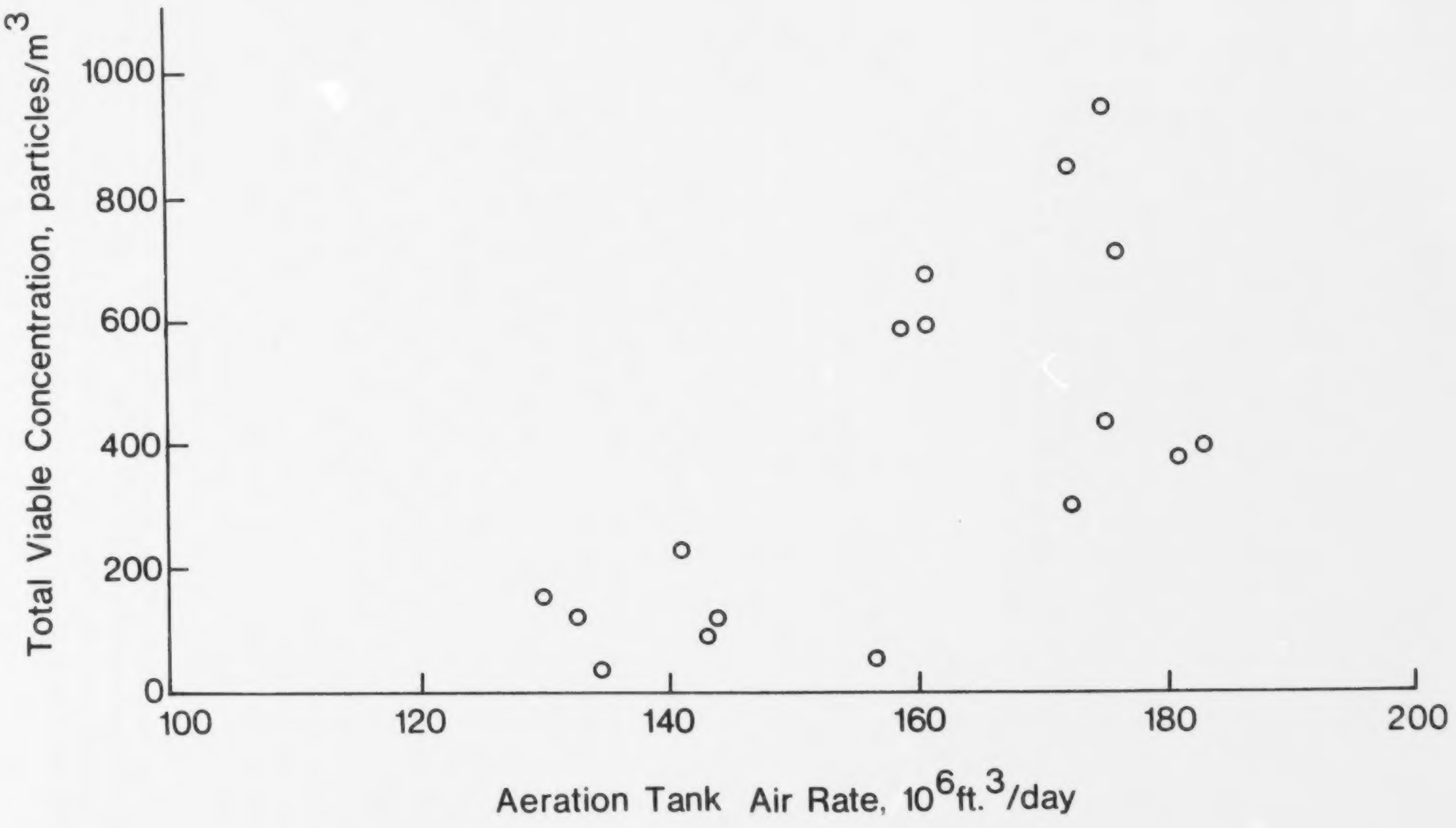

Figure 21. Total viable particle concentration versus aeration tank air rate.

Total viable particle and coliform in air were compared using regression analysis with temperature, humidity, wind speed and direction, solar radiation and ultraviolet radiation for the plant and 0.8-km upwind and downwind positions. No discernible relationships were found between total viable particle and coliform concentrations and humidity, temperature, solar radiation, UV radiation, or wind direction. The plot between wind speed and total viable particle concentration 0.8 km downwind of the plant (Figure 22) did show the characteristic negative sloping envelope found with relationships between other air pollutants and wind speed.

A two-way analysis-of-variance was used to test the significance of the differences between the mean concentrations at the four positions and whether they were sampled during the day or night. No significant day-night differences were found for either total viable particles or total coliform, whether sites 6 and 14 were included or not ($p > 0.05$). For this analysis, classification by day or night was considered an indicator of meteorological conditions during sampling. In order to further delineate the effects of meteorological conditions, a multiple regression was done with wind speed, temperature, and relative humidity as the independent variables and total viable particle concentration as the dependent variable. Due to the low r^2 of 0.11 (percentage of the variance explained by these three variables) these meteorological parameters cannot be considered to have a significant effect on total viable particle concentration. Even less of the differences between total coliform concentrations can be explained by wind speed, temperature, and relative humidity ($r^2 = 0.048$) using this same method.

The lack of correlation between viable measurements and meteorological variables is perhaps not unexpected. In general, it might be suggested that solar radiation, low relative humidities, low wind speeds, and high temperatures would give low viable particle recoveries. However, the available data appear to be somewhat equivocal in this regard. For instance, Goff et al. (2) reported higher recoveries of both total bacteria and coliform at night than during the day. However, this effect may have been due to higher nighttime relative humidities. King et al. (5) reported increased recoveries with higher temperatures. Kenline and Scarpino (4) did not observe any trends with relative humidity or solar radiation, although their data possibly suggested better recoveries with higher humidities. Randall and Ledbetter (7) observed no variation in recovery with relative humidity or temperature, but did report a rough positive relationship between number of bacteria and relative humidity when the wind speed factor was suppressed. Adams and Spendlove (1) suggested that solar radiation and humidity were important factors but did not present a systemized analysis of their data. Fannin et al. (57) found a significant inverse correlation between coliform concentration and ambient air temperature but no relationship between coliform and relative humidity. Lee et al. (75) found no appreciable association between total viable bacteria concentrations and temperature or relative humidity. Conclusive interpretation of these studies is also difficult due to the different methodologies used to collect bacteriological aerosols. Evaluation of more subtle effects than we have observed here awaits a more exhaustive analysis than time permitted.

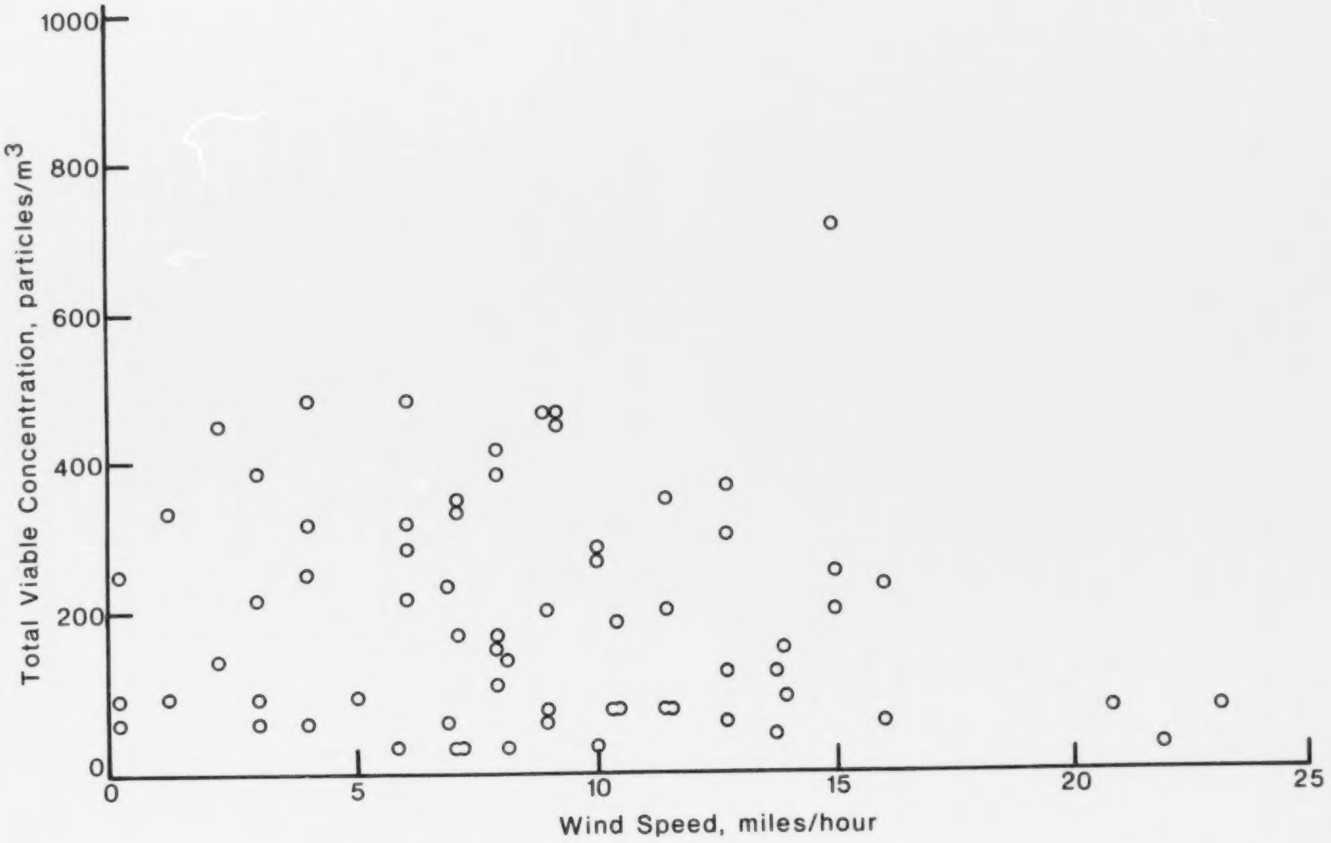

Figure 22. Total viable particle concentration 0.8 km downwind of the plant versus wind speed.

No relationships (regression analysis) were found between plant non-viable measurements and any plant operating or sewage characteristic. The off-plant sites B, C, D, and E were analyzed by comparing upwind and downwind measurements made at each site. No relationship was found between TSP, $SO_4^=$, NO_3^- and any sewage or operating parameter. Sites C, D, and E are all 1.6 km away from the plant. Combining these three sites for the wind direction analysis also did not produce any relationship between a non-viable pollutant and a sewage characteristic or plant operating characteristic.

Even though a variety of trace elements were found in the sewage (TABLE 58) most are apparently not discharged into the air in sufficient quantities to be notable. The same was true for nitrates and sulfates. The lack of correlation between operating parameters and any of the non-viable pollutants is somewhat puzzling, particularly in light of the fact that both sewage throughput and air rate independently varied by almost a factor of two. Apparently the quantities of sulfates, nitrates, and trace elements which are aerosolized do not measurably contribute to the existing background concentrations. It may be that aeration tank surface area and air discharge velocity are more important factors for emission of pollutants to the atmosphere.

The observations noted above for viable and non-viable concentration relationships with meteorological and plant operating data are based only on a preliminary analysis. No notable trends are evident. However, a complete evaluation of all the possible interactive effects has yet to be carried out. It is also significant to note that the concentrations of total viable and coliform particles were lower than have been reported by other investigators of trickling filter plants (Adams and Spendlove (1), Goff et al. (2), Napolitano and Rowe (8), and Fannin et al. (57)). When comparing the results of this study with measurements made at other activated sludge plants, the total viable particle concentrations reported here were somewhat higher than those reported by Pereira and Benjaminson (32); comparable to those measured by Napolitano and Rowe (8) and Johnson et al. (22); and much lower than those reported by Randall and Ledbetter (7). The total coliform bacteria concentrations measured in this study using Andersen samplers can only be compared to one study which also used Andersen samplers at an activated sludge plant (57). The results of that study are higher than those reported here, but distances of the samplers from the aeration tanks were not given. The lower values reported in this study are probably due to the low velocity design of the air-addition pipes (10-30 μm porosity ceramic diffuser plates), to the unusually deep aeration tanks (4.2-4.6 meters), and to the fact that no sludge treatment facilities are located at the plant. In addition, the measured concentrations of non-viable materials were usually quite low.

INTEGRATION OF HEALTH AND ENVIRONMENTAL DATA

Introduction

The major purpose of this study was to determine whether or not a sewage treatment plant is a health hazard to a community. This was investigated by integrating the environmental exposure data with the health data for the study population in the community. The environmental data provided exposure indices for total viable particles (total aerobic bacteria-containing particles), total coliform bacteria and non-viable pollutants (TSP, metals, and gases) for each household for the 8-month study period. The Health Watch data provided household illness and infection rates for the same period. The seroepidemiological survey provided the most valid incidence rates of infection, but for only a few, selected viruses. Finally, the retrospective health questionnaire survey permitted the identification of persons potentially at high risk to the health effects of viable and non-viable pollution exposure.

A dose-response approach was taken in the analysis of exposure and health effects. Regression analyses were performed to determine if health effects increased with exposure, or if the two variables varied independently. Scatter diagrams were prepared to further examine the relationship between exposure and health effects.

Acute Illness and Total Viable Particle Exposure

Acute Illness Rates and Total Viable Particle Exposure--

Total viable particle exposure indices for the 8-month study period were compared with acute illness rates for each of the 290 Health Watch households. Eight-month exposure indices were calculated with and without sites 6 (upwind) and 14 (downwind) since these sites reflected a source of total viable (downwind) particles other than the plant (see Figure 20). The range and mean in particles/m^3 for the exposure indices using all sites were 86 to 265 and 155, respectively. The range and mean for the indices excluding sites 6 and 14 were 86 to 264 particles/m^3 and 158 particles/m^3, respectively. In relating illness rates to total viable particle exposure, it was necessary to limit the illnesses to those types which potentially might have a causal association with viable particle exposure. With this in mind, the illness rates were based on self-reported (diary) acute illnesses equal to or greater than one day duration and were calculated for respiratory, gastrointestinal, eye and ear, skin, and total illnesses. The 290 8-month household total illness rates ranged from 0 to 71.43 and averaged 7.31 illnesses per 1000 person-days of exposure.

Regression analyses of the 8-month household total viable particle exposure indices and the corresponding 8-month household acute illness rates were performed. No linear relationship ($p > 0.05$) was found for these variables with or without sites 6 (upwind) and 14 (downwind). This was true for the separate illness categories as well as all types of illnesses combined. All of the correlation coefficients were < 0.1 and not significantly different ($p > 0.05$) from zero. Scatter diagrams of total illness rates and respiratory illness rates against total viable particle exposure indices (calculated both ways) did not reveal any apparent relationships missed by the regression analysis. The lack of correlation between 8-month total viable particle exposure and illness rates may be the result of an inadequate sample size (in terms of number of households), an unequal frequency distribution of household exposure indices in terms of not having enough households exposed at "low" or "high" levels of total viable particle concentrations, the inaccuracies in self-reported illness rates, the existence of more complex functional relationships between the health and exposure variables, or no relationship at all.

Temporal Acute Illness/Total Viable Particle Exposure Relationships--

Regression analyses between illness and exposure were also performed on a 2-week averaging period basis. These periods correspond to the Health Watch data-collection periods. The same illnesses used for the total viable particle analyses discussed above were calculated as 2-week period rates. Not enough total viable particle measurements existed for the first data-collection period (April 3-16) so the analyses were performed for only the last 16 2-week periods. No linear relationships ($p > 0.05$) were found for the 2-week periods when analyzed separately or together for all types of illnesses or for respiratory illnesses only. Respiratory illnesses were considered separately since they represented a large proportion of the total illnesses reported.

In order to examine a possible lag effect between exposure and illness, a 2-week lag period analysis was carried out. This was accomplished by correlating a 2-week period's illness rates with the previous 2-week period's exposure indices. A 2-week period was the smallest lag period possible to analyze. Again, no linear relationship ($p > 0.05$) between 2-week illness rates and total viable particle exposure measured 2 weeks prior to the illness period was detected.

In addition to the explanations for lack of correlation provided in the previous section, it was also possible that the 2-week lag period was too long in terms of incubation period for most bacterial and viral agents possibly associated with these illnesses. It was also important to note that the 2-week exposure indices were much less reliable measurements than those based on the total study period.

Acute Illness Rates for High Risk Subgroups and Total Viable Particle Exposure--

An attempt was made to examine the relationship between illness and exposure for various subpopulations potentially at high risk to the effects of total viable particle exposure. Age, chronic respiratory disease, chronic gastrointestinal problems, smoking, family composition (presence of young children), and length of residence in the study area were considered potential risk factors. Regression analyses between the 8-month illness rates (as separate categories and as total illnesses) and exposure indices were carried out controlling for each of these high risk groups.

The acute illnesses defined above were used to calculate rates for persons within households belonging to a specific high risk subgroup. A person-exposure index was taken to be equal to a person-household exposure index. The correlation coefficients for four age groups (0-12, 13-18, 19-59, and > 59 years) did not reveal any linear relationships ($p > 0.05$) between illness and exposure. A similar finding was derived for the 70 people with chronic respiratory disease (chronic bronchitis, emphysema, or asthma).

The correlation coefficients for persons with chronic gastrointestinal problems were not significantly different ($p > 0.05$) from zero. Regression analyses of smokers (current) and non-smokers also resulted in correlation coefficients not significantly different ($p > 0.05$) from zero. Family composition was categorized as follows: (1) families with only one or two members (all adults); (2) families with youngest child aged 0 to 5 years; (3) families with youngest child between 5 and 14; and (4) families with youngest child over 13 years old. All but one correlation coefficient ($r = 0.27$ for skin illnesses for families with youngest child between 5 and 14) were not significantly different ($p > 0.05$) from zero. Length of residence was considered in terms of less than 1 year, 1 to 5 years, 6 to 10 years, 11 to 20 years, and over 20 years of residence in the study area. All but one coefficient ($r = 0.39$ for skin conditions in the over 20 years of residence group) were not significantly different ($p > 0.05$) from zero. The correlation coefficients obtained for skin conditions for families with youngest child between 5 and 14 years old and for greater than 20-year residents are based on mean illness rates of 0.25 and 0.07 skin conditions per 1,000 person-days of exposure, respectively, and are therefore of questionable importance.

In summary, regression analyses of acute illness and total viable particle exposure with consideration given to high-risk variables did not result in any significant linear relationships. Again, the lack of any apparent linear correlation between exposure and illness may be due to inadequate sample sizes, an inadequate representation of exposure levels, inaccuracy of the illness data, or the existence or nonexistence of more complex relationships. Because of the consistent lack of any significant relationships when each independent variable was considered singularly, any multiple regression analysis would also be of no significance.

Summary Discussion of Acute Illness Rates and Total Viable Particle Exposure--

Regression analyses of acute illness rates and total viable particle exposure as described above did not reveal any significant linear relationships. The concern that these results were possibly due to an inappropriate exposure index was pursued. The exposure index incorporates upwind (background) exposure as well as downwind (plant contribution). If a qualitative difference exists between organisms present in the background concentrations and those originating from the sewage treatment plant, then an index reflecting only the contribution of the plant would be better for the study of sewage treatment plant health effects. It was also possible that since the plant's contribution to the average exposure index is not very great (the plant only strongly impacts, with respect to total viable particles, the limited number of people living near it), variations in background exposure may mask the health effects of plant organisms. A "plant-source bacteria" exposure index was calculated by taking the difference between the total exposure index (which incorporates downwind and upwind of plant data) and the background concentrations. Regression analysis of the acute illness rates and 8-month "plant" exposure index (total viable particles) resulted in no significant results ($p > 0.01$).

It was of interest that the regression analysis results obtained with the "plant-source bacteria" exposure index support those obtained using the total exposure index. It should be pointed out, however, that the "plant" index was not initially used because one of its two factors, the background index, represents only 25 percent of the airborne total viable particle measurements. This results in an increase of the uncertainty of the plant index when compared to the total exposure index. For this reason and because no change in statistical results occurred, the "plant" index will not be applied to further analyses.

Acute Illness and Total Coliform Bacteria Exposure

Regression analyses of total coliform bacteria exposure indices and corresponding acute illness rates were made for each household. The total coliform bacteria exposure indices cover a 12-week period since total coliform measurements did not begin until September 13. The range of the 290 household exposure indices (all sites) was 0.25 and 3.55 particles/m^3 with a mean of 1.42 particles/m^3. The illness rates used for this analysis were based on the same criteria described for the total viable particle analyses and correspond to the data collection periods covered by the exposure index (Sept. 18 to Nov. 26). No linear relationship ($p > 0.05$) was found for respiratory illnesses or for all illnesses combined.

Illness and Exposure to TSP, Metals, and Gases

The 8-month exposure indices developed for NO_2, SO_2, TSP, NO_3^-, $SO_4^=$, V, Mn, Cu, and Pb represent an adequate characterization of the study area exposure for those non-viable constituents. Although these constituents were found not to be associated with the sewage treatment plant, regression analyses between exposure and illness were performed to search for an association between these constituents and health.

The illness rates used in these regression analyses were those presented in TABLE 36. No linear relationship ($p > 0.05$) was found between the household illness rates and corresponding household exposure indices for any of the nine constituents. This was the case for all illnesses combined as well as for the separate illness categories (respiratory, gastrointestinal, skin, etc.). Scatter diagrams of the illness rates and corresponding exposure indices also did not reveal any apparent linear relationships.

Infection Rates and Total Viable Particle Exposure

Throat and Stool Specimens--

As was shown in TABLE 43, 174 bacterial organisms were isolated from throat cultures of children 0 through 12 years of age. Throat bacterial infection rates were developed as follows:

$$\begin{array}{l}\text{throat bacterial infection} \\ \text{rate per 1,000 person-days} \\ \text{of exposure}\end{array} = \frac{\Sigma \text{ unique bacterial isolations}}{\begin{array}{l}\Sigma \text{ days present in study area} \\ \text{for every 2-week data-collection period a throat culture was received}\end{array}} \times 1{,}000$$

These rates were then compared to the total viable particle exposure indices. In Figure 23, the bacterial infection rates were plotted for S. aureus and all other bacteria combined. Staphylococcus aureus was specifically plotted because it is most frequently transmitted from person to person and is unlikely to be of environmental origin. Both rates of bacterial infection were unrelated to total viable particle exposure; the two distributions of infection rates were similar. Thus, there appears to be no dose-response relationship between viable particle exposure and bacterial infections. Regression analysis confirmed the lack of a linear relationship between infection rates and total viable particle exposure (correlation coefficient = 0.07).

Serosurvey--

Analysis of virus infections was possible by comparison of the total viable particle concentration of household exposure with infections due to coxsackieviruses and Echoviruses as determined serologically. Regression analysis of the initial virus antibody titers and total viable particle exposure indices was carried out for each of the coxsackieviruses and Echoviruses. None of the correlation coefficients were significantly different ($p > 0.05$) from zero. TABLE 64 shows the number of sera tested that showed a fourfold rise in antibody and the number of sera tested in which a rise was not found for any of the five coxsackieviruses and four Echoviruses tested. Also shown are the mean total viable particle exposure associated with each serological group. The total viable particle exposure was less for persons with no seroconversions (160) compared to those with at least one antibody rise to one of the types of coxsackieviruses (175). A different pattern was observed for the Echovirus conversions which suggested an inverse relationship between exposure and frequency of infection. The differences observed were not remarkable enough to suggest that the risk of infection was greater or less due to increased exposure to total viable particles.

TABLE 64. SUMMARY OF TOTAL VIABLE PARTICLE EXPOSURE FOR VIRAL SEROCONVERSIONS

	Total viable particle exposure, particles/m^3	
No. antibody rises/sera for:	Mean	Range
Coxsackieviruses B1-5		
0 (272)[a]	160	86 - 411
$\geq$ 1 (46)	175	86 - 411
Echoviruses 3, 6, 9, 12		
0 (292)	163	87 - 411
$\geq$ 1 (25)	145	86 - 392

[a] No. in parentheses indicates no. of sera tested.

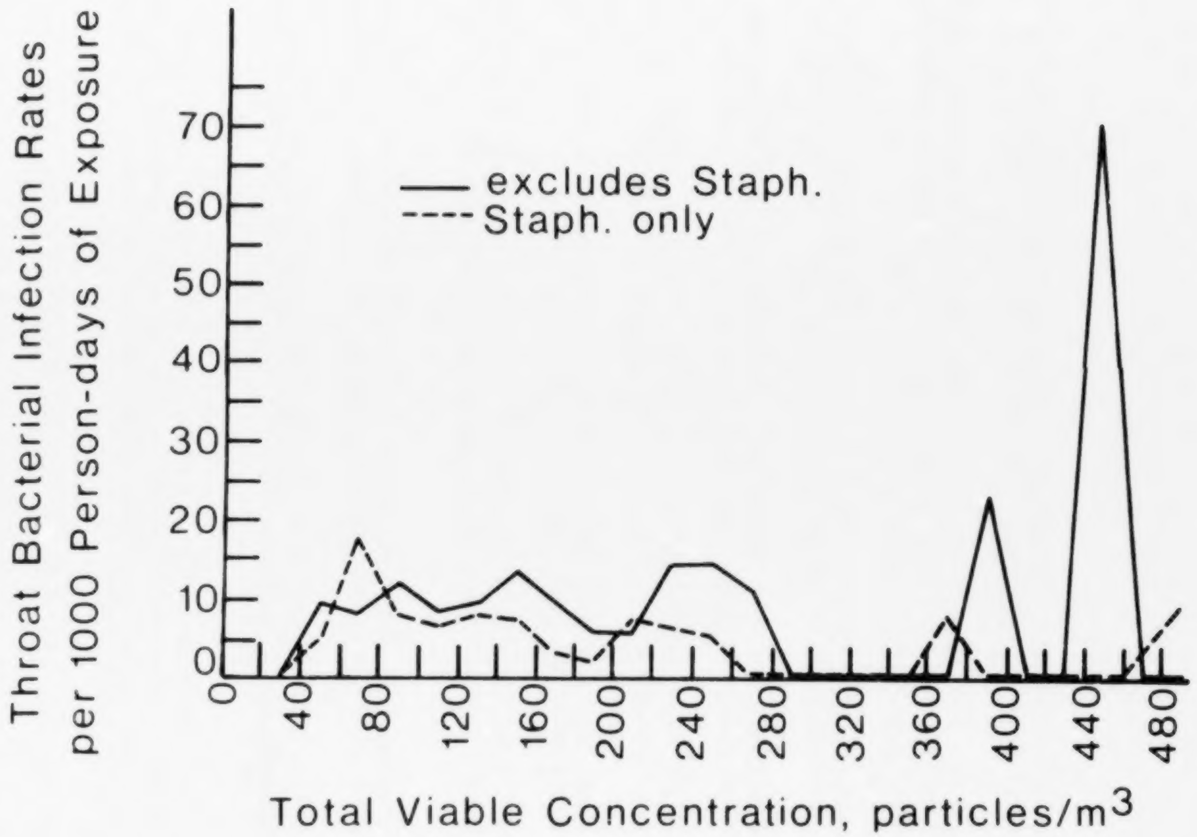

Figure 23. Respiratory infection rates versus total viable particle exposure.

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APPENDIX A

METHODOLOGY FOR MICROBIOLOGICAL ANALYSIS AND SEROSURVEY OF CLINICAL SPECIMENS

The laboratory procedures for bacteria and virus isolation in throat and stool specimens, and for serological procedures were proposed and conducted as outlined below.

1. Throat Swab Specimen

Two throat swab specimens (one swab for bacteriological analysis, the second for virus study) will be collected once every 2 weeks over a period of 8 months. All specimens will be delivered to the State Laboratory within 24 hours of collection. The State Laboratory shall provide the University of Illinois sterile throat swabs and media where appropriate for the throat and fecal specimens described below.

a. Bacteria

Analytical procedures used will follow those stated in the 1974 "Manual of Clinical Microbiology", 2nd ed.; "Diagnostic Procedures", 5th ed. APHA; and "Identification of Enterobacteriaceae", Edwards and Ewing, 1972.

A dry cotton swab is used to obtain a specimen from the pharynx and tonsil area, including any exudate present.

The swab specimen is returned to the sterile paper envelope or is placed in a sterile test tube which will be identified by subjects' name and a serial laboratory number.

Upon receipt at the laboratory, the swab specimen is inoculated onto five different agar media in 100 mm plastic petri dishes. These plates will be streaked (5% sheep blood agar, bile esculin, eosine-methylene blue (EMB), Baird-Parker or Staphylococcus 110 egg yolk, Hektoen-Enteric agar plates) with a wire loop and incubated aerobically at 35-36°C for 16-24 hrs.

Plates will be examined macroscopically for abnormal bacteria flora.

1. Gram positive bacteria will be identified using standard microbiological procedures.

2. 3 pickings of selective gram negative bacterial colonies will be inoculated into a set of 5 tubes containing different media (peptone broth, triple sugar iron agar (TSI), mannitol broth, Christenson's urea agar, lysine decarboxylase broth). Those bacterial pickings requiring further testing for complete identification will be inoculated onto an API-20 test kit. Specific antisera will be used to serotype any salmonella, shigella, or enteropathogenic E. coli. Possible E. coli isolates will be inoculated onto MR/VP broth and citrate agar. Nonenteric organisms may be studied further using Leifson's media and other microbiological techniques.

All laboratory findings will be noted on laboratory workcards and reported on listing sheets.

b. Viruses

Throat, nasopharyngeal and laryngeal swabs should be collected in 2 cc respiratory transport medium (8 g NaCl, .2 g KCl, 1.15 g Na_2HPO_4, 4 g bovine albumin, 5 ml Gentamycin - per 100/ml). Swabs are wrung out. Supernate is treated with 1 cc of 4x antibiotic diluent for 30 minutes and then immediately inoculated into TC system.

Each throat specimen will be inoculated onto the following cell cultures systems:

1. Primary Rhesus Monkey Kidney (Rh MK)
   Growth Media (GM): 5% FCS - 95% 199 - L. Glutamine.

2. Human Embryonic Fibroblast (Flow 5000) GM: 10% FCS - 5% T PO_4 - 85% 199 - L. Glutamine.

3. Human Epithelial Carcinoma (HEP-2) GM: 10% FCS - 90% MEM - L. Glutamine.

   Maintenance Media (MM) for all lines consists of 5% inactivated FCS - 95% MEM.

   Standard TC concentrations of Penicillin-Streptomycin-Polymyxin B and Amphotericin B are incorporated into both GM and MM.

   Sodium Bicarbonate is used as a buffering system.

Tissue culture inoculation protocol will be as follows:

Enteric Virus Isolation - Treated specimens are inoculated into at least 2 tubes of each cell line on MM in a volume of 0.1 cc. Tubes are incubated at 35° - 37°C in standard stationary tissue culture racks with a 5° slant. Tubes are held for two weeks and observed microscopically for viral cytopathogenic effect (CPE).

The following references were used for the virus isolation technique:

Schmidt, N.J., Tissue Culture Techniques for Diagnostic Virology, pp. 79-178, in Diagnostic Procedures for Viral and Rickettsial Infections, ed. E.H. Lennette & N.J. Schmidt, 1969, IV edition, Am. Pub. Hlth. Assoc. Inc., New York.

Laboratory Diagnosis of Viral Diseases, Course No. 8241-C, pp. 11-14, 94, 98-99, U.S. Dept. H.E.W., Public Health Service, CDC, Atlanta.

2. Fecal Swab Specimens

Fecal specimens will be collected to analyze for bacteria and viruses. All specimens will be delivered to the State Laboratory within 24 hours of collection. All specimens for virus analysis will be cooled in ice immediately after collection and during delivery.

a. Bacteria

Analytical procedures used will follow those stated in the 1974 "Manual of Clinical Microbiology", 2nd ed.; "Diagnostic Procedures", 5th ed. APHA; and "Identification of Enterobacteriaceae", Edwards and Ewing, 1972.

Specimen is obtained using a swab sample from the patient's feces. The swab is placed into a tube containing Amies transport medium with the tube identified by subject's name and a laboratory serial number.

Upon receipt at the laboratory, the swab is inoculated onto EMB, Hektoen-Enteric, bismuth sulfite agar plates and selenite enrichment broth media which are incubated aerobically for 16-24 hrs. at 37°C, the bismuth sulfite plate for 48 hrs.

1. Plates are examined macroscopically for pathogenic gram negative bacteria.

2. The selenite enrichment broth is used to inoculate another Hektoen-Enteric agar plate when the primary plates showed no significant growth. The plate is incubated for 16-24 hrs at 37°C.

b. Viruses

Feces (swabs or stool) - Swabs are removed from carrying media, wrung out and discarded. One milliliter of 4x antibiotic diluent is added to carrying media. Stools are suspended as a 5-10% solution in 4x antibiotic diluent. Fecal specimens are then centrifuged at 15,000 RPM/30 minutes to remove debris.

Supernatant is aseptically decanted and inoculated into TC or stored at -20°C until ready for inoculation.

The following cell cultures will be employed:

1. Primary Rhesus Monkey Kidney (Rh MK)
   Growth Media (GM): 5% FCS - 95% 199 - L. Glutamine.

2. Human Embryonic Fibroblast (Flow 5000) GM: 10% FCS - 5% T PO_4 - 85% 199 - L. Glutamine.

3. Human Epithelial Carcinoma (Hep-2) GM: 10% FCS - 90% MEM - L. Glutamine.

   Maintenance Media (MM) for all lines consists of 5% inactivated FCS - 95% MEM.

   Standard TC concentrations of Penicillin-Streptomycin-Polymyxin B and Amphotericin B are incorporated into both GM and MM.

   Sodium Bicarbonate is used as a buffering system.

The tissue culture inoculation protocol is as follows:

Enteric Virus Isolation - Treated specimens are inoculated into at least 2 tubes of each cell line on MM in a volume of 0.1 cc. Tubes are incubated at 35° - 37°C in standard stationary tissue culture racks with a 5° slant. Tubes are held for two weeks and observed microscopically for viral cytopathogenic effect (CPE).

The following references were used for the virus isolation technique:

Schmidt, M.J., Tissue Culture Technics for Diagnostic Virology, pp. 79-178, in Diagnostic Procedures for Viral and Rickettsial Infections, ed. E.H. Lennette & N.J. Schmidt, 1969, IV edition, Am. Pub. Hlth. Assoc. Inc., New York.

Laboratory Diagnosis of Viral Diseases, Course No. 8241-C, pp. 11-14, 94, 98-99, U.S. Dept. H.E.W., Public Health Service, CDC, Atlanta.

3. Blood Specimens

a. Virus serology

Each blood sample will be allowed to clot and will be stored in ice chests and will be delivered to the State Laboratory within 24 hours of collection. Serum from each blood sample will be analyzed for 10 virus antibody levels. The initial sera will be stored at -20°C and analyzed when the second sample is available. Poliovirus, echovirus, and coxsackie B neutralization test in microtiter assay will be performed as follows:

I. Peagents

A. Medium 752 - Source: GBI

B. Viral and sera diluent.

10% Fetal calf sera (inact. 30' at 56°C)
90% 752
200 u/cc Penicillin
200 ug/cc Dehydrostreptomycin
35 u/cc Polymixin B Sulfare
5 ug/cc Fungizone

C. Cell medium

10% FCS (Inact. 30' at 56°C)
90% Medium 752
5 cc/100 cc 2.8% $NaHCO_3$ stock
1 cc/100 cc of 100X L-Glutamine
(same antibiotic concentrations as used in viral diluents)

D. 70% Ethanol

E. Mineral Oil

II. Microtiter Plate.

Soak all plates for 1 hour in 70% EtOH to remove toxicity. Expose to UV for 1 hour.

III.

A. Make up viral dilutions as follows:

10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}

Change pipettes for each dilution. Refrigerate until ready to use.

B. Dispense diluent, virus dilution, cell suspension and mineral oil in the following amounts into each well:

0.025 ml diluent
0.025 ml virus dilution
0.025 ml cell suspension
0.10 ml mineral oil

KEEP CELL SUSPENSION WELL SHAKEN

Set up one full plate for each virus plate extra for controls. Controls have 0.05 ml diluent, but no virus dilution.

C. Incubate plates at 37°C for 72 hours. Observe plates each day to note progress or cell growth and virus actions. Record cytopathological effect as + or -.

D. After 72 hours record all positions. Determine average dilution of virus showing CPE. Count back two dilutions to give 100 TCD concentration. Use this dilution in serum testing.

IV. Serum Testing

A. Dilute sera 1/4 and inactivate at 56° for 30'.

B. Make dilutions in plate of 1/8-1/1024. Allow one serum control at lowest dilution used for each serum tested.

C. Add 100 TCD of virus to the serum dilutions and incubate at room temperature for 1 hour. Add cell suspensions and mineral oil and incubate at 37°C for 72 hours.

D. Run complete virus titration concomitantly.

E. In testing positive sera allow one plate for each serum and 4 rows of wells for each virus titration. Use all extra holes as cell controls.

V. Cell Preparation - Hep-2

A. Wash the cell sheath 3x with a BSS free of divalent ions.

B. Add a 1x trypsin-versene solution and allow it to remain on the cell sheath for 1 minute. Remove the trypsin-versene and add the cell suspension medium. Let the bottle stand erect for 10 minutes and then shake the cell loose. Agitate well with a pipette and then count the cells in a hemocytometer.

C. Cells are suspended at 320,000/cc to give 8000 cells per 0.025 cc.

References:

Schmidt, N.J., Tissue Culture Technics for Diagnostic Virology, pp. 79-178, in *Diagnostic Procedures for Viral and Rickettsial Infections*, ed. E.H. Lennette & N.J. Schmidt, 1969, IV edition, Am. Publ. Hlth. Assoc., Inc., New York.

Laboratory Diagnosis of Viral Diseases, Course No. 8241-C, pp. 11-14, 94, 98-99, U.S. Dept. H.E.W., Public Health Service, CDC, Atanta.

APPENDIX B

SURVEY OF VIABLE PARTICLE SAMPLING SITES (Nos. 5-20)

Site	Description
5.	Central Pk. and Keeney Industrial area, no food processing, residential area begins 1 block north on west side of street.
6.	MSD Field Serv. parking lot Site located approximately 30 paces from west edge of lot and 60 paces from river (to the west). Industrial area located to south and east of site, warehouses to north.
7.	Bell and Howell parking lot Approximately 4.6 meters of grass and stones to lot; 73 paces west thru to edge of lot (which was just open field - grass and stones, during sampling period); then about 15-18 meters further to canal.
8.	McCormick Blvd. Site located across street from Fel-Pro. Approximately one-half block to east: Sanitary Canal, separated from site by construction at least 0.8 km long, parallel to canal.
9.	Jarvis and St. Louis All industrial (no food processing). Immediately next to site (to S.W.): open land, weedy ("No Dumping" area). Area: 1 square block. At south edge of land: "Batch - Pac".
10.	Jarvis and Hamlin Residential to west, some industry to north, east, and south. Within one-half block south: Knechtel Science Research Laboratories (7341 Hamlin).
11.	Brummel and E. Prairie Residential to north, west, and east. 1 block east: park (starts at Hamlin), about 1 block wide, then rest of way east is open land

and then plant (MSD). Two blocks north: RR tracks (Skokie Swift). Immediately S.W. (across street): school (E. Prairie Elem.) Two short blocks south and within one block west: delicatessen, hair salon, laundromat (on Howard).

12. Hamlin and Oakton

All residential to north; restaurant/snack shop 1 short block east; fast-food fried chicken shop 0.4 km to west.

13. Lee and Drake

Residential. One block to south: Main St., with small business shops, etc., beginning 2 blocks east of Drake on Main (includes deli/restaurant).

14. Cleveland and Hartrey

Residential, except to S.W.: Evanston water tower, and to south and west of that: industry, including coke storage (Marquette Coal and Mining). Two blocks north and one-half block west: EZ Spuds.

15. Dobson and Dodge

Residential to north, west, and east. One short block south (Howard Street): fast-food fried chicken, with two other restaurants next to it (going east on south side of Howard). Going west on Howard (on south side): Cantonese carry-out restaurant, deli, bakery. N.W. corner, Howard and Dodge: restaurant.

16. Sacramento and Fitch

Residential to east, south and north. School and community center across street to east. North one block (Touhy Avenue) and then east for about 0.8 km: commercial (shops, etc.). Within 1 block east (of Sacramento and Touhy): Chop-Suey Shop, bakery, pizza restaurant. Second block east: large doughnut shop.

17. Lawndale and Hunt

Industrial (no foods) surrounding site, except for grassy field immediately N.E., one-half square block area.

18. Karlov and Estes

Residential for blocks around, in all directions.

19. Lowell and Brummel

All residential. One block north: Skokie Swift RR tracks. One block west: park. One block west and 1 block south: White Hen Pantry (small grocery/sandwich store).

20. Madison and Karlov

Residential. One block north: Main St. (with small shops, etc.) including bakery, laundry, to east.

APPENDIX C

METHODOLOGY AND RESULTS FOR ENVIRONMENTAL BACTERIA, BACTERIOPHAGE, AND VIRUSES

MATERIALS AND METHODS

Animal Virus Assay

Cell Cultures--

Human epidermoid carcinoma of larynx cell cultures (HEp-2) were obtained from Illinois State Health Department Laboratories. Cultures were grown at 37°C in disposable plastic 490 cm^2 Corning roller bottles and split 1:3 at 4 to 6 day intervals. For subpassage, monolayers were washed three times with calcium- and magnesium-free Hank's Balanced Salt Solution (HBSS) and exposed for 3 min to 0.25% trypsin in pH 7.4 phosphate buffered saline (PBS). The trypsin solution was decanted and the monolayers were incubated at 37°C until the cells began to slough-off of the surface of the bottle. Cells were resuspended in growth media and diluted to approximately 3 to 4 x 10^5 cells/ml. Primary African Green Monkey Kidney cells (PMK) with SV_5 and SV_{40} antisera were obtained from the Grand Island Biological Co., Grand Island, NY and diluted with growth medium to approximately 2.5 x 10^5 cells/ml. The cells were refed with fresh growth medium after 24 hr at 37°C under 5% CO_2.

Cell Culture Media--

Cultures of HEp-2 cells were subpassaged on growth media consisting of Minimal Essential Medium (MEM) containing 10% fetal calf serum (FCS) (Grand Island Biological Co., Grand Island, NY), 50 μg/ml Gentamicin and 2.5 μg/ml Fungizone. For PMK cell cultures, the same growth medium, without Fungizone, was used. For maintenance, monolayered cultures were refed with MEM containing 2% heat-inactivated (56°C for 30 min) fetal calf serum (HIFCS) and antibiotics, as described. Plaque assay overlay media consisted of MEM supplemented with 2% HIFCS, 4% of 1:1000 dilution neutral red, 1% of 50% $MgCl_2$ $6H_2O$, 50 μg/ml Gentamicin or 200 units/ml penicillin and 200 μg/ml streptomycin, 2.5 μg/ml Fungizone, and 1.5% Difco-Bacto agar.

Mycoplasma Screening--

To test for presence of mycoplasma, 1 ml concentrates of each cell culture were inoculated into 10 ml of Difco PPLO broth without crystal violet, supplemented with Difco Mycoplasma Supplement S. At the same time, 0.1 ml of the sample was inoculated onto the surface of duplicate petri plates each containing 6 ml of the PPLO broth plus 0.9% Oxoid

Ionagar No. 2. One plate was incubated aerobically and the other anaerobically at 37°C. After 4 days, 0.1 ml of the broth was transferred to each of two additional agar plates and incubated as described at the same time, 1 ml of broth was transferred to a new broth tube that, after 4 days incubation, was transferred to agar plates. All plates were examined microscopically (300X) at 2 to 3 day intervals for 14 days. Presumptive Mycoplasma was confirmed by Dienes stain retention, presence of subsurface colony growth, and ability to grow when subcultured.

Plaque Assay--

Growth medium was aspirated from 100 mm Corning plastic tissue culture dishes monolayered with HEp-2 or PMK cells and washed twice with Earles Balanced Salt Solution (EBSS) containing 10 mM HEPES buffer, 2.5 µg/ml Fungizone, 200 units/ml penicillin, and 200 µg/ml streptomycin. The monolayered cells were inoculated with 1 to 2 ml of processed sample. (Normally, no more than half of the sample allocated to a specific cell line was assayed during any particular assay procedure.) To monitor virus toxicity of the sample, an appropriate dilution of poliovirus type 1 suspension was added to a processed sample aliquot, mixed, and similarly inoculated onto replicate cell cultures. Positive virus and uninoculated cell culture replicates were included with each assay. All control virus inoculations were performed in a Class II type 1 laminar flow hood separate from those used for either sample processing or sample assay.

Inoculated cell cultures were incubated, with periodic agitation, at 37°C for 60 min for virus adsorption. These cultures were again washed with EBSS and, under subdued lights, 15 ml of overlay medium at 45°C was added to each plate. After solidification, the plates were inverted, covered with aluminum foil, and incubated at 37°C in 5% CO_2 atmosphere. The plates were observed daily after 2 days and the plaques were marked and harvested upon observation for at least 8 days. Each assay was validated by qualitative observation of control plates.

Plaque Harvest and Passage--

Plaques were harvested from sample and control plates by removing a plug of plaque-containing overlay agar, while simultaneously scraping the underlying cell sheet with a sterile disposable transfer tube and placing it in a sterile vial containing 2 ml of EBSS with HEPES buffer and antibiotics, as described. Plaque isolates were held at -70°C until passage in homologous cell systems. For passage, tubes of monolayered cell cultures were washed twice with EBSS, inoculated with 0.5 ml of freshly thawed plaque-plug suspensions and incubated at 37°C for 60 min for virus adsorption. The tubes were fed with MEM containing 2% HIFCS and reincubated at 37°C. Positive virus plaques and uninoculated cell control plaque plugs were similarly passaged. In addition, appropriate poliovirus type 1 suspension dilutions were inoculated into replicate tubes and uninoculated tubed cell cultures were included with each assay. The tubes were observed daily for cytopathic effect (CPE) after 48 hr for at least 8 days or until the control cell monolayers were lost. Tubes demonstrating CPE were frozen at -70°C and repassaged using a similar procedure. Tubes demonstrating CPE on the second passage, without apparent bacterial or fungal contamination, were considered positive virus isolates and were frozen at -70°C. All plaque harvesting and passage procedures were performed under indirect lighting.

Coliphage Assay

Coliphage assays were performed on samples obtained from the wastewater aeration tank. Liquid samples were processed by the Freon 113 or $Al(OH)_3$- continuous flow centrifugation procedures and air samples by the Freon 113 procedure. Phages of Escherichia coli C300 were assayed by the soft agar overlay method using 4 hr cultures of E. coli C3000, grown in phage assay broth (PAB). The PAB was prepared by adding 8.0 g nutrient broth; 5.0 g NaCl; 0.20 g $MgSO_4$ $7H_2O$; 0.05 g $MnSO_4 \cdot H_2O$ to a final volume of 1 liter of distilled water and adding 0.15 g $CaCl_2$ to the solution. The PAB with agar (PABA) was prepared by adding 15 or 7 g Difco agar to 1000 ml of PAB. To each tube, containing 2.5 ml of PABA with 0.7% agar and maintained at 45°C, 0.1 ml of host culture suspension and 1 ml of each sample or appropriate sample dilution was added. Liquid samples from the aeration tank were assayed in 10-fold dilutions while processed air samples were assayed without dilution. Tubes were mixed and poured onto 1.5% PABA plates and evenly spread by swirling and rocking the plate. The plates were incubated 5 to 18 hr and the plaques were counted using a Quebec colony counter. Control plates for the host cultures, base agar, and positive growth of MS-2 phage were incubated with each assay.

Bacterial Assay

After vigorous agitation of liquid samples from the aeration tank, approximately 50 ml were placed in a suitable container and blended for 4 min at medium speed in a Virtis mixer. Samples were then assayed for total coliform, fecal coliform, and total viable bacteria. Total and fecal coliform assays employed the membrane filtration procedures (Standard Methods, 14th ed., 1965). Appropriate duplicate sample dilutions were filtered through 47 mm diameter 0.45 μm pore size Millipore filters which were placed on absorbant pads in 50 mm plastic petri dishes containing either m-Endo or m-FC medium for total or fecal coliform assays.

Total coliform plates were incubated at 35°C for 24 hr and characteristic "metallic sheen" colonies were counted under fluorescent light using a binocular dissecting microscope. Fecal coliform plates were placed in water tight containers and incubated in a water bath at 44.5°C for 24 hr. Characteristic blue colonies were counted using a similar procedure. Large volume air samples were similarly assayed for coliform bacteria but without the initial processing. Total viable bacteria were assayed by plating 0.1 ml of appropriate sample dilutions in duplicate on trypticase soy agar (TSA) containing 0.01% actidione by the spread plate technique. The plates were incubated at 35°C for 48 hr and colonies counted using a Quebec colony counter.

Air Sampling Procedure Development and Selection

Andersen Six-Stage Viable Air Samplers--

Andersen six-stage viable air samplers were calibrated to sample at 28.3 liters per min. Throughout the project, 27 ml of BBL trypticase soy agar (TSA), prepared according to the manufacturer's instructions, were poured into glass Andersen petri plates and, after solidification, incubated overnight at 35°C. When no evidence of colonial growth was observed on the plates, they were loaded into four six-stage viable air samplers for UI personnel pickup. The samples were collected, incubated, and counted for total aerobic bacteria-containing particles by University of Illinois (UI). Due to occasional fungal overgrowth after 48 hr incubation at 35°C, inclusion of a mold inhibitor into the media was considered. Before routine use of a fungal inhibiting additive, four separate aeration tank samples from the North Side Sewage Treatment Works (NSSTW) were assayed in duplicate at appropriate dilutions for total aerobic bacteria on TSA plates with and without 0.01% actidione (TABLE C-1). Since no consistent differences were observed with and without actidione, it was included routinely in TSA plates.

TABLE C-1. TOTAL AEROBIC BACTERIA FROM AERATION TANK SAMPLES ON TSA PLATES WITH AND WITHOUT 0.01% ACTIDIONE

	Aerobic bacteria (cfu/0.1 ml x 10^4)	
Sample	0.01% Actidione	Without Actidione
1	10.5	3.0
2	20.0	18.5
3	4.5	6.5
4	8.0	6.0

Andersen sample collection for total coliform, as well as for total aerobic bacteria-containing particles, was initiated after September 22, 1977. The medium employed was Difco m-Endo broth, prepared according to the manufacturer's instructions, except that it contained 1.5% Difco Bacto-Agar. The medium was poured in 27 ml volumes into glass Andersen plates and into plastic petri dishes incubated at 37°C overnight and plates showing no colonial growth were either loaded into Andersen samplers for field use by UI personnel or used for spread plate assays. After air sampling, the plates were incubated at 35°C for 24 hr by UI and either refrigerated or brought immediately to IITRI for counting. Characteristic metallic green colonies were counted under fluorescent light with a binocular microscope. Because low airborne concentrations were anticipated, the total coliform growth-supporting-capacity of the m-Endo Agar used for each sampling trial was verified by parallel duplicate aeration tank assays of appropriate dilutions, by both the spread plate and membrane filtration procedures (TABLE C-2). No significant differences were found between the two procedures ($t = -0.62$, $df = 29$).

Large Volume Air Samplers--

Large volume air sample collection for total and fecal coliform bacteria employed the LVAS sampler. The LVAS was also used for airborne coliphage sample collection, until cancellation during August, and for airborne animal virus sampling. An effort was made to make the sample decontamination and air sampling protocol as uncomplicated and concise as possible. Several alternative methods for large volume air sample decontamination in the field were considered. The decontamination procedure used prior to coliform sampling is outlined in TABLE C-3. After decontamination, 10 ml of the sampling fluid were collected to be assayed as a "toxicity" control for seeded dilutions of *E. coli*. The fluid flow rate was adjusted to 6 to 10 ml/min and 100 ml of sampling fluid were collected directly onto a membrane filter for assay as a "contamination" control. Sampling was initiated at an air flow rate of approximately 1.0 m^3/min as determined by previous manometer calibrations by the manufacturer. The recommended electrostatic precipitator voltage was 14Kv, although UI personnel indicated that actual sampling was frequently performed at 10Kv in order to reduce electrical arcing. During sampling, air sample-containing fluid was collected in a 0.45 µm pore size 47 mm diameter membrane filter in a Millipore filtration apparatus. Both experimental and contamination control samples were filtered and assayed by UI for total or fecal coliform, using tubed m-Endo or m-FC media (*Standard Methods*, 14th ed., 1975). After 24 hr incubation at 35°C the plates were either refrigerated or returned immediately to IITRI where the characteristic colonies were counted.

Prior to sampling for airborne coliphages with the LVAS, an alcohol-hot water procedure was recommended for sampler decontamination (TABLE C-4). The protocol basically involved a 100 ml wash of 70% ethyl alcohol, with 0.01% methylene blue, followed by a boiling water wash for 30 min after the temperature of the sample effluent reached 56°C. Sample collection was not initiated until the effluent temperature was reached to at least 27°C. Field application of this procedure was limited because the low voltage resulted in extended time requirements for production of boiling water and because wind conditions often cooled the sampler, delaying attainment of the 56°C temperature in the sampler effluent.

To reduce field time requirements and to provide a suitable LVAS decontamination method prior to coliphage or animal virus sampling, a procedure employing live steam and ultraviolet light was devised. Prior to field application, the usefulness of this procedure was evaluated in a coliphage-contaminated sampler. A 75 ml aliquot of sterile water, containing 5.2×10^7 pfu/ml MS-2 phage, was run through a LVAS at a rate of approximately 9 ml/min. The effluent was collected and assayed for MS-2 phage on *E. coli* C3000 by the soft agar overlay procedure. The sampler peristalic pump was released and the inlet and outlet sampler tubing was connected to live steam for 15 min. Excess condensate which formed on the sampler rotating disc was removed with a sterile syringe and needle. A

TABLE C-2. TOTAL COLIFORM COUNTS FROM AERATION TANK SAMPLES ASSAYED BY MEMBRANE FILTER AND SPREAD PLATE PROCEDURES

Date (1977)	Total coliform (cfu x 10^5/ml)	
	Membrane filter on m-Endo broth	Spread plate on m-Endo broth with 1.5% agar
9-13	1.4	13.4
9-14	6.5	14.0
9-19	5.8	12.8
9-21	8.0	14.0
9-25	14.4	16.7
9-28	14.2	8.6
9-29	2.0	5.8
10-4	6.6	3.6
10-5	8.8	7.4
10-9	24.0	6.0
10-11	7.4	4.0
10-13	5.1	6.2
10-17	2.2	9.4
10-19	7.0	6.3
10-25	4.9	5.8
10-27	7.8	7.8
10-31	2.2	5.1
11-2	3.0	8.0
11-2	4.8	8.8
11-6	4.0	8.8
11-8	3.0	7.0
11-10	2.0	2.8
11-14	8.0	8.7
11-16	12.6	8.2
11-20	5.7	1.8
11-22	4.7	1.4
11-24	13.3	1.9
11-28	2.5	3.4
11-30	3.5	6.2
11-30	3.1	4.9

TABLE C-3. LVAS DECONTAMINATION (COLIPHAGE, ANIMAL VIRUS, AND COLIFORMS)

1. Turn on main power switch.
2. Remove sampler wall and release peristalic pump tension.
3. Connect sampler inlet and outlet tubing to steam generator and turn on heating unit.
4. After steam is formed, permit flowing steam to pass through both the inlet and outlet tubing for 15 min.
5. Using a sterile syringe and needle, aseptically remove excess moisture from sampler rotating disc as needed.
6. Place ultraviolet light fixture above sampler rotating disc for 15 min.
7. Aseptically readjust peristalic pump tension and close sampler.
8. Flush 200 ml sterile water through sampler.
9. Aseptically collect 20 ml of final flush into sterile vacutainer tube for decontamination verification.

TABLE C-4. LVAS DECONTAMINATION (COLIPHAGE)

1. Bring 2 liters of RO water to boil.

2. Connect sampler inlet line to blue wash No 2 (70% alcohol). Run 100 ml of wash through sampler (discard effluent).

3. Insert inlet line into boiling water.

4. Insert inlet tubing from LVAS and peristalic pump into boiling water.

5. Insert tip of outlet peristalic pump tubing into groove of rotating disc in LVAS (via slightly cracked LVAS lid).

6. Place heat lamp on air inlet of LVAS and secure with clamp.

7. Turn on main power switch of LVAS. Turn on fluid pump switch of LVAS. Turn on peristalic pump switch. Adjust all pumps to high. Turn heat lamp on.

8. Monitor temperature fluid from LVAS outlet. Observe level of water in groove of rotating disc. Be sure it does not overflow disc. If air bubbles are present in outlet line, adjust fluid pump.

9. After above fluid has reached 56°C, continue process for 30 min.

10. After 30 min:

    a. Turn off heat lamp, remove and replace with aluminum foil.

    b. Turn off peristalic pump and remove tubing from groove of rotating disc (ASEPTICALLY).

    c. Place LVAS inlet tube in sterile cold HQ water. Hold in ice bath. Use vent needle.

    d. Monitor LVAS outlet temp. until it reaches at least 27°C (cooler if possible under ambient conditions).

11. Sampler is now ready for sample collection.

germicidal ultraviolet lamp (GE G15T8-15 watt) was then placed at approximately 10 cm above the rotating sampling disc which was exposed to the UV light for 15 min. The peristalic pump was readjusted, the sampler closed, and 200 ml of sterile water was flushed through the sampler at about 13 ml/min for approximately 15 min. The final flush (10 ml) was then collected and assayed for MS-2 phage. Approximately 3.8 x 10^7 pfu/ml were counted in the sampler effluent before decontamination compared to 0 pfu/ml on five assayed plates after decontamination.

Air samples for animal virus and coliphage assay were collected by methods described by Fannin et al. (Appl. Environ. Microbiol. 31: 705, 1976). The LVAS was operated at an air sampling rate of approximately 1.0 m^3/min, with 14.0-15.0 Kv through the electrostatic precipitator and a sampling fluid flow rate of 7 to 9 ml/min, depending upon environmental conditions. Sampling fluid, consisting of 30 ml of PBS, containing 2% of the 1% phenol red solution, 0.03% GE Antifoam 10, and 2% HIFCS was used. The sampling fluid was recirculated through the sampler and maintained at a constant volume by replacing evaporated water (TABLE C-5). The reservoir containing this fluid was kept in an ice bath during the sampling period. Field samples were processed and assayed as soon as possible. Animal virus samples that were not assayed immediately were frozen at -70°C. The LVAS was decontaminated between each sample by the flowing steam-germicidal UV lamp procedure.

The operating procedures for the LVAS for coliform sampling were the same as described above except that on the recommendation of UI the collecting fluid was PBW with 25% trypticase soy broth (TSB) and was not recirculated. The steam and UV method was used for decontamination because it was found to be effective, did not require the additional toxicity control, and provided a uniform method of decontamination for sampling operations.

Sample Processing for Viral Isolation

Wastewater Aeration Tank Samples--

Freon 113 processing and direct inoculation--Wastewater aeration tank samples were initially processed for animal virus and coliphage isolation by a Freon 113 procedure for direct inoculation onto cell cultures. Approximately 200 ml of each sample was mixed with 10X EBSS containing 10 mM HEPES buffer and adjusted to pH 9.5 with 1N NaOH. The sample was agitated with a Virtis mixer at medium speed for 4 min, sonicated for 30 sec with a Branson sonifier at 4.5 amps, and centrifuged at 600 x g for 30 min. The supernatant was adjusted to pH 7.2 with 1N HCl, an equal volume of Freon 113 was added, the mixture was vigorously agitated, and held overnight at 4°C. The aqueous phase was again centrifuged at 600 x g for 30 min and the supernatant assayed for coliphage and animal virus.

Aluminum hydroxide-continuous flow centrifugation concentration--When increased sensitivity for animal virus detection was found to be

TABLE C-5. SAMPLE COLLECTION-LVAS

1. Allow LVAS to pump remaining final rinse water out of lines. Collect final 20 ml of final rinse and label. Hold sample at 4°C.
2. Connect large (7cmx18g) sterile needle aseptically to inlet tube of LVAS.
3. Wipe top of collecting fluid vial with 70% alcohol.
4. Insert inlet line needle aseptically into vial.
5. Insert vent needle aseptically into vial.
6. Place collecting fluid vial in ice bath.
7. Wipe top of empty vial with 70% alcohol and insert outlet line needle and vent needle.
8. Allow LVAS to pump collecting fluid through unit and collect first 20 ml. (Label pre-sample sterility control; store at 4°C.
9. Quickly transfer outlet line needle aseptically to collecting fluid vial (same vial inlet line is attached). Mark level of collecting fluid in vial immediately at completion of pre-sample sterility control sample. (Attach sterile syringe filled with sterile water to vial aseptically).
10. At end of sampling period, shut off voltage and blower, remove LVAS inlet line and insert needle into sterile water vial. Allow collecting fluid to collect in sample vial until fluid is clear. (Approx. 30 ml). Shut LVAS pump off. Disconnect sample vial and store at 4°C.
11. Flush LVAS with water.

necessary, aeration tank samples were concentrated using an aluminum hydroxide-continous flow centrifugation technique developed and evaluated in IITRI laboratories. All samples were held at 4°C after receipt and processed within 8 hr. Prior to processing, $Al(OH)_3$ was freshly prepared by adding 3 ml of 2M Na_2CO_3 to 100 ml of 25 mM $AlCl_3$ and adjusted and maintained during a 15 min stirring period at pH 7.2. The precipitate was centrifuged at 500 x g for 15 min and resuspended in an equal volume of 0.15 M NaCl. The liquid fraction of approximately 5 liters was decanted into an iced reservoir and the remaining solids-associated suspension was adjusted to pH 9.5 with 5 N NaOH, placed in appropriate containers, sonicated with a Branson sonifier at 4.5 amp for 30 sec, and centrifuged at 500 rpm for 30 min. The supernatant was added to the initial liquid fraction, adjusted to pH 6.0 with 5 N HCl, and 1% of freshly prepared $Al(OH)_3$ suspension added. After 1 hr mixing in an ice bath, during which the pH was held constant, the sample was centrifuged at 27,000 x g in a continuous flow centrifuge (KSB system with a Sorvall Model RC2-B) at a flow rate of 200 ml/min. Precipitated materials were resuspended in pH 10.5 glycine buffer, containing 2% sodium-EDTA and 10% HIFCS, sonicated for 10 sec with a Branson sonifier at 4.5 amps, and adjusted to pH 9.5 with 0.1 N NaOH. After a 10 min stirring the suspension was centrifuged for 15 min at 27,000 x g. The supernatant was decanted, filtered through a HIFCS pretreated 47 mm diameter 0.45 µm Millipore or a 0.4 µm Unipore filter, and mixed with 10% of a 10X concentration of EBSS containing HEPES. A final concentration of 50 µg/ml of Gentamicin and 5 µg/ml Fungizone was added and the sample frozen at -70°C until assayed.

Processing procedure verification--Studies in which animal virus was recovered from seeded environmental samples using both the Freon 113-direct inoculation and aluminum hydroxide-continuous flow centrifugated procedures were performed. Samples were seeded with laboratory preparations of poliovirus type 1 strain LSc 2ab. Care was exercised throughout these experiments to ascertain that no field sample contamination occurred. All apparatus which came in contact with virus were autoclaved or soaked in a sodium hypochlorite solution immediately after use.

For seed virus preparations approximately 100 pfu of poliovirus type 1 strain LSc 2ab were inoculated into roller bottles containing Buffalo Green Monkey (BGM) kidney cell monolayers washed three times with HBSS. The inoculated culture was incubated in a roller apparatus for 60 min at 37°C to permit virus adsorption, and 100 ml MEM with 2% HIFCS and 10 mM HEPES buffer was added. Incubation continued until the cell monolayer began to slough off due to virus produced CPE or approximately 48 hr. The cell-virus suspension was decanted, vigorously mixed with 5% chloroform, refrigerated at 4°C for 4 hr, and centrifuged at 600 x g for 30 min. The supernatant was decanted into 10 ml tubes, titered by the plaque assay procedure, and stored at -70°C until used.

Immediately prior to use, the suspension was thawed and diluted to about 10^3 or 10^4 pfu/ml in EBSS with 10 mM HEPES buffer and the virus suspension was "deaggregated" by filtration through a 0.05 µm Unipore filter. An appropriate volume of filtered suspension was then added to the aeration tank influent sample collected from the North Side WWTP. The sample volumes were approximately 200 ml for Freon 113-direct inoculation or 5 liters for $Al(OH)_3$-continuous flow centrifugation. The seeded suspension was stirred at low speed for 30 min at 4°C and then processed by the appropriate procedure for virus recovery. A plaque titration was performed on a portion of the filtered virus used in each study to determine the number of virus pfu initially seeded.

The recovery of seeded virus from NSSTW aeration tank samples was found to be greater than 57% for all trials (TABLE C-6). The recovery efficiency was found to be higher with the Freon 113-direct inoculation procedure but the concentration factor using this technique was 200 times lower and, consequently, less sensitive than that of the aluminum hydroxide-continuous flow centrifugation procedure.

Thirty-four viral isolates were collected and processed as described above. The identification of three enterovirus groups was performed by tissue culture procedures described in APPENDIX A.

Large Volume Air Samples--
Samples were mixed and adjusted to pH 9.5 with 0.1 N NaOH, sonicated for 30 sec with a Branson sonifier at 4.5 amps, and centrifuged for 30 min. The supernatant was adjusted to pH 7.2 with a 0.1 N HCl, an equal volume of Freon 113 added, and after vigorously mixing, the sample was held at 4°C overnight. The aqueous fraction was removed and centrifuged at 600 x g for 30 min. The supernatant was filtered through a 0.4 µm Unipore membrane filter and the filtrate was assayed immediately for coliphages and the remaining portion was held at -70°C until assayed for animal virus.

RESULTS

Aeration Tank Samples

Coliphage--
Escherichia coli C3000 phage counts from wastewater aeration tank samples shown in TABLE C-7 ranged from 2.2×10^3 to 8.6×10^5 pfu/liter.

Animal Virus--
Using the Freon 113-direct inoculation procedure 45 ml wastewater, contained in 50 ml processed sample, were assayed on HEp-2 and PMK cells. Plaques were observed in all HEp-2 and in all but one PMK cell assays with concentrations in PMK cells ranging from < 22 to 222 pfu/liter and in HEp-2 cells from 156 to 444 pfu/liter (TABLE C-8). None of the observed plaques, however, demonstrated CPE after two passages in homologous cell systems. Since no viruses were confirmed, their concentrations were estimated to be < 22 plaque forming viral units (PFVU) per liter in wastewater aeration tank samples using the direct inoculation procedure. Although this method was demonstrated to recover 66% and 93% seeded virus

TABLE C-6. RECOVERY OF POLIOVIRUS TYPE 1 FROM SEEDED AERATION TANK SAMPLES BY FREON 113-DIRECT INOCULATION AND $Al(OH)_3$-CONTINUOUS FLOW CENTRIFUGATION

Method	Sample volume (ml x 100)	Concentration factor	Final volume (ml)	Virus (pfu x 10^3)		Recovery %
				Inoculum	Recovery	
Freon 113	1.8	1	205	1.34	0.89	66
Freon 113	1.9	1	226	4.52	4.18	93
$Al(OH)_3$	50.0	200	25	5.17	3.12	60
$Al(OH)_3$	50.0	200	25	112.34	64.55	57

TABLE C-7. ESCHERICHIA COLI C3000 PHAGES FROM WASTEWATER AERATION TANK

Date (1977)	Aeration tank sample source	Processing method	Coliphage concentration (PFU/liter)[a]
5-3	Inf + Eff[b]	F[c]	8.2×10^5
5-16	Inf + Eff	F	2.0×10^5
6-13	Inf + Eff	F	8.6×10^5
7-5	Inf + Eff	F	5.7×10^4
7-11	Inf + Eff	F	1.6×10^5
7-25	Inf	F	1.6×10^5
7-25	Eff	F	1.2×10^5
9-14	Inf	A	4.3×10^3
9-29	Inf	A	1.2×10^5
9-29	Eff	A	1.2×10^4
10-5	Inf	F	2.2×10^3
10-5	Eff	A	3.3×10^4
10-13	Inf	F	1.6×10^4
10-13	Eff	F	7.2×10^3
10-19	Inf	F	1.6×10^5
10-19	Eff	F	1.8×10^4
10-27	Inf	F	1.8×10^4
10-27	Eff	F	7.2×10^3
11-3	Inf	F	1.8×10^4
11-3	Eff	F	2.3×10^5
11-10	Inf	F	1.2×10^5
11-10	Eff	F	1.2×10^5
11-17	Inf	F	9.0×10^4
11-17	Eff	F	1.1×10^5

[a] Based on duplicate 1 ml assays of 10 fold dilutions.

[b] Inf and Eff refer to aeration tank influent and effluent, respectively.

[c] F - Freon 113 processing. A - $Al(OH)_3$ processing.

TABLE C-8. ANIMAL VIRUS RECOVERY FROM 45 ML WASTEWATER AERATION TANK SAMPLES USING FREON 113-DIRECT INOCULATION PROCEDURE

Date (1977)	Source	Cell system	PFU observed (no.)	PFU/l	First passage CPE (no.)	Confirmed virus (no.)
5-16	Inf + Eff[a]	PMK	10	222	0(5)[c]	0
		HEp-2	20	444	1(9)	0
6-13	Inf + Eff	PMK	2	44	0	0
		HEp-2	16	356	9	0
7-5	Inf[b]	PMK	0	<22	-	0
		HEp-2	7	156	1	0
7-11	Inf + Eff	PMK	7	156	0	0
		HEp-2	17	378	1(2)	0(1)
7-25	Inf	PMK	9	200	0	0
		HEp-2	19	422	3	0
7-25	Eff	PMK	8	178	0	0
		HEp-2	8	179	1	0

[a] Aeration tank influent and effluent designated by Inf and Eff, respectively.

[b] One sample only received.

[c] Number of plaques found to be bacterial or fungal contaminants in parenthesis.

from wastewater aeration tank samples (TABLE C-6) the volumes processed were estimated to be below those required for routine animal virus detection from the study source.

Consequently, an alternative processing procedure permitting concentration of large sample volumes prior to assay was considered, evaluated, and employed for virus concentration from wastewater aeration tank samples. The virus data obtained from these samples using the $Al(OH)_3$-continuous flow centrifugation procedure are presented in TABLE C-9. Plaques were observed in both the PMK and HEp-2 cell systems for most of the samples assayed. The concentrations were, however, lower than those observed by direct inoculation and ranged from < 0.4 to 16.3 pfu/liter in PMK cells and from < 0.4 to 3.9 pfu/liter in HEp-2 cells. Animal viruses were confirmed in 54% of the samples when assayed in PMK cells but no confirmation was made in any samples assayed in HEp-2 cells. When viruses were found, their concentrations ranged from 0.3 to 7.1 pfvu/liter. Using seeded virus, however, the procedures used recovered 57% and 60% of the virus seeded in similar samples (TABLE C-6).

The influent and effluent samples obtained between the end of August and November 17, 1977 were processed for animal viruses as described above. Thirty-four isolates of cytopathogenic agents were made from nine sewage samples collected on eight separate days. Identification of these was crudely conducted with pools of type-specific poliovirus antisera and with separate pools of Coxsackievirus types B1 through 5 specific antisera (TABLE C-10). Nine of the 34 isolates were polioviruses obtained from five of the nine sewage samples. None of the isolates were neutralized by the pool antisera for Coxsackievirus B1-5. The remaining 25 agents were cytopathogenic for primary cultures of monkey kidney cells in 72 hours post-inoculation. These non-poliovirus, non-coxsackieviruses may have included other enteroviruses such as the Echoviruses. It was concluded that polioviruses and other cytopathic agents can be recovered from aeration tank influents and effluents, but they may not be found in sewage aerosols if they are bound to large particulate matter in the sewage and not free to be aerosolized.

Aerosol Samples

Animal Viruses--

Four air samples were collected for animal viral assay in the vicinity of the wastewater aeration tanks. Although plaques were observed in both upwind downwind samples, none was confirmed as virus (TABLE C-11). Limitations in availability of equipment and shifts in wind conditions during sampling prevented collection of larger volumes of air and corresponding increased sampling sensitivity. In addition, the samples were divided for assay on both PMK and HEp-2 cell systems which further reduced the air volume represented in each assay by about one-half. The maximum air volume sampled was 180 m^3 or about 180,000 liters.

TABLE C-9. ANIMAL VIRUS RECOVERY FROM WASTEWATER AERATION TANK SAMPLES USING $Al(OH)_3$ CONCENTRATION PROCEDURE

Date (1977)	Source	Cell system	Volume assayed (ml)	Sewage volume (ml)	PFU observed (no.)	PFU/1	First passage CPE (no.)	Confirmed virus (no.)	PFVU/1
8-30	Inf[a]	PMK	15.0	2490	12	4.8	4	2(2)[b]	0.8
		HEp-2	15.0	2490	4	1.6	3	0	<0.4
9-14	Inf	PMK	6.5	1547	24	16.3	13(2)	11(2)	7.1
		HEp-2	10.0	2380	0	<0.4	-	0	<0.4
9-29	Inf	PMK	5.0	1485	0	<0.7	-	0	<0.7
		HEp-2	1.0	297	1	3.4	1	0	<3.4
9-29	Eff	PMK	13.0	3198	2	0.6	1	1	0.3
		HEp-2	9.0	2214	0	0.4	-	0	<0.4
10-5	Inf	PMK	24.0	2952	2	0.7	0(1)	0	<0.3
		HEp-2	24.0	2952	8	2.7	8	0	<0.3
10-5	Eff	PMK	5.5	1832	5	2.7	4	4	2.2
		HEp-2	5.5	1832	2	1.1	0(1)	0	<0.5
10-13	Inf	PMK	13.0	2834	0	<0.4	-	0	<0.4
		HEp-2	13.0	2834	2	0.7	1	0	<0.4
10-19	Inf	PMK	16.3	2364	2	0.8	0(1)	0	<0.4
		HEp-2	16.3	2364	4	1.7	1	0	<0.4

(continued)

TABLE C-9 (continued)

Date (1977)	Source	Cell system	Volume assayed (ml)	Sewage volume (ml)	PFU observed (no.)	PFU/1	First passage CPE (no.)	Confirmed virus (no.)	PFVU/1
10-19	Eff	PMK	6.8	2264	2	0.9	0	0	<0.4
		HEp-2	6.8	2264	3	1.3	2	0	<0.4
10-27	Inf	PMK	11.0	2332	5	2.2	3(1)	3	1.3
		HEp-2	11.0	2332	3	1.3	1	0	<0.4
10-27	Eff	PMK	14.7	2381	2	0.8	0	0	<0.4
		HEp-2	14.7	2381	4	1.7	0	0	<0.4
11-3	Inf	PMK	12.1	2505	13	5.2	7	7	2.8
		HEp-2	12.1	2505	3	1.2	1	0	<0.4
11-3	Eff	PMK	17.5	2310	1	0.4	0	0	<0.4
		HEp-2	17.5	2310	9	3.9	0	0	<0.4
11-10	Inf	PMK	7.0	2093	6	2.8	1	1	0.5
		HEp-2	7.0	2093	7	3.4	1	0	<0.5
11-10	Eff	PMK	13.8	2305	6	2.6	1(4)	1	0.4
		HEp-2	13.8	2305	3	1.3	0	0	<0.4
11-17	Inf	PMK	14.5	2422	8	3.3	1(3)	1	0.4
		HEp-2	14.5	2422	2	0.8	0	0	<0.4
11-17	Eff	PMK	1.9	295	2	6.9	0	0	<3.4
		HEp-2	1.9	295	1	3.4	0	0	<3.4

[a] Aeration tank influent and effluent designated by Inf and Eff, respectively.

[b] Number of plaques found to be bacterial or fungal contaminants in parenthesis.

TABLE C-10. VIRUS IDENTIFICATION OF AERATION TANK SAMPLES

Sample date	Aeration tank sample location	Virus identification[a,b]
8/30/77	Influent	PV
		NPCV
9/14	Influent	PV
		NPCV
		NPCV
		NPCV
		NPCV
		PV
		NPCV
		PV
		PV
		NPCV
		PV
		NPCV
		NPCV
9/29	Effluent	NPCV
10/5	Effluent	NPCV
		NPCV
		NPCV
		NPCV
10/27	Influent	NPCV
		NPCV
		NPCV
11/3	Influent	NPCV
		NPCV
		NPCV
		NPCV
		NPCV
		PV
		NPCV
11/10	Influent	PV
11/10	Effluent	NPCV
11/17	Influent	PV
		NPCV

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[a] Listed for each second-passaged plaque.
[b] PV = Poliovirus isolate; NPCV = Non-polio, non-coxsackie virus

TABLE C-11. AIRBORNE ANIMAL VIRUS FROM LVAS SAMPLES IN VICINITY OF WASTEWATER AERATION TANKS

Date (1977)	Location	Air volume (m^3)	Fluid volume (ml)	Cell system	Air volume assayed (m^3)	PFU observed (no.)	First passage	Confirmed virus (no.)
9-29	Upwind	120	35	PMK	60	0	-	0
				HEp-2	60	2	1	0
9-29	Downwind	180	30	PMK	88	7	1	0
				HEp-2	90	3	0	0
10-27	Upwind	120	31	PMK	53	8	0	0
				HEp-2	53	2	0	0
10-27	Downwind	120	38	PMK	56	3	1	0
				HEp-2	56	11	4	0

APPENDIX D

PRECISION OF TOTAL VIABLE PARTICLE COUNTING PROCEDURES

Three hundred and seventy one plates were double counted from 9/19/77 to 11/1/77. One of the University of Illinois project monitoring team (P. Pekron) acted as a reference for the other three members of the counting team. The measurements were evaluated using the "technical error of measurement" test (1):

$$S = \sqrt{\frac{\sum_{i=1}^{n} d^2}{2n}}$$

where n is the number of pairs of measurements in the study, d^2 is the square of the difference between members of the i^{th} pair of measurements (i = 1 .....n) and s = the technical error of measurement. The technical error, s, can be interpreted as a coefficient of variation, and is a dimensionless constant. It essentially describes the size of measurement error. It is applied to the differences in counts in the following ways:

$$\text{should} \quad |X-Y| > 3s$$

it is assumed that the difference is not expected and is due to some error in counting (X being Pekron counts, Y being the counts of other workers).

3s is chosen arbitrarily as is a "p" value (such as p = 0.01) in testing a normal hypothesis. Thus, 3s is essentially equivalent to 3 standard deviations, meaning 99 percent of these values should fall in this "3s" range. The differences which are due to a miscount (determined by this statistical method) are circled on Figure D-1. As can be seen in Figure D-1, only 12 out of 371 counts did not fulfill this criterion. For these 12 points, only the Pekron counts were used. For all the rest the two counts were averaged. Double counting was carried out to the end of the project with the same averaging procedure.

Reference (1): National Center for Vital and Health Statistics Series 11, No. 152, Washington, D.C., 1975.

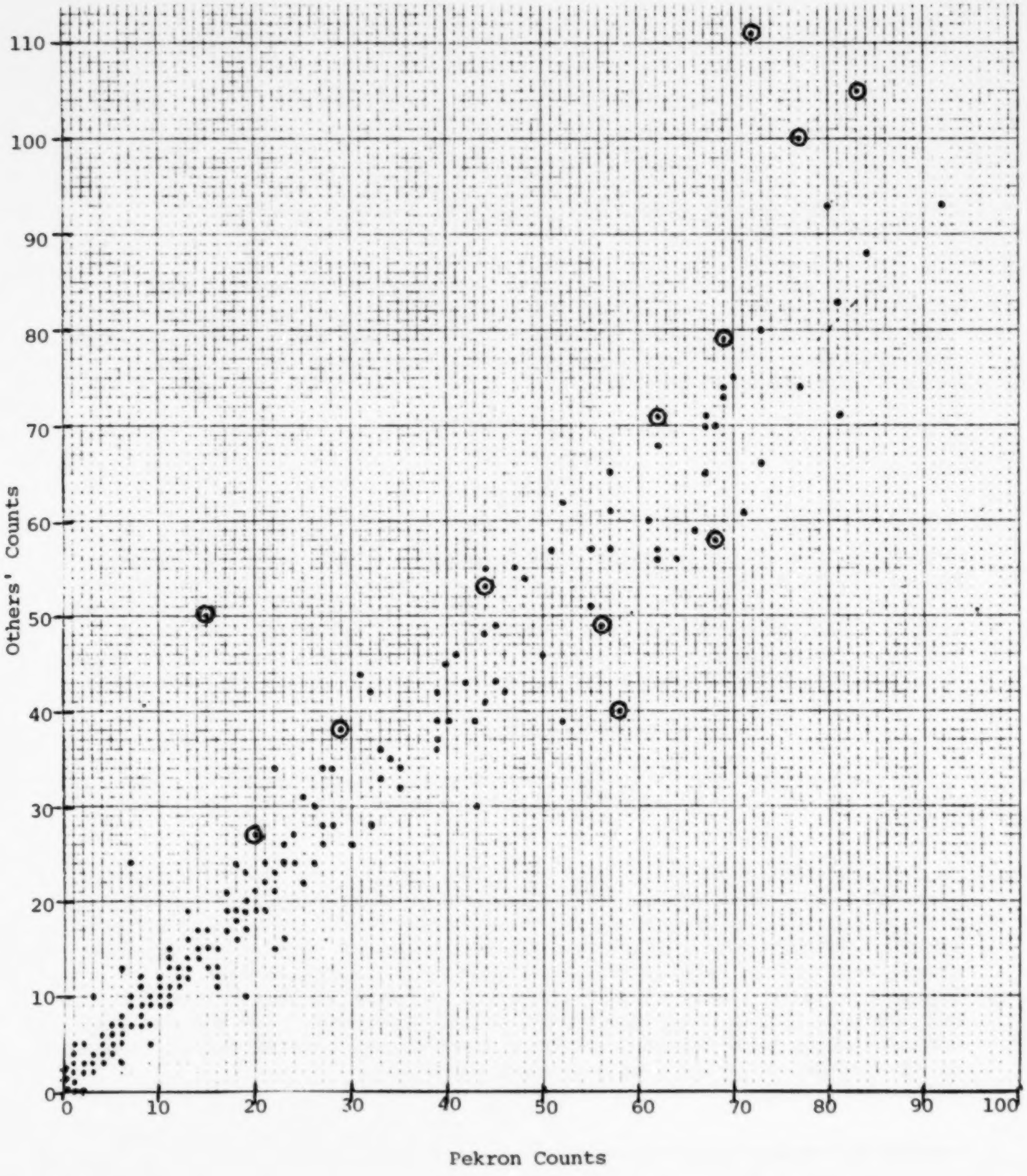

Figure D-1. Pekron counts vs. others' total viable particle counts.

APPENDIX E

ENVIRONMENTAL DATA

TABLE E-1. TOTAL VIABLE PARTICLES IN AIR DATA SET

OBS	DATE	LOCATION	CNCODE	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	TCONC	WD	TIME	INCTIME	POSITION	X
1	.	.		.	.	.	.	.	.	.	.	.	.	.	ONEDN	.
2	4.18	4	D	80	39	29	6	7	6	167	371.111	90	1435	50	PLANTON	.
3	4.18	7	D	90	21	22	14	7	8	162	360.000	90	1600	50	HALFUP	.
4	4.18	11	D	93	58	29	14	10	4	208	462.222	90	1535	50	HALFDN	.
5	4.18	19	D	38	25	14	26	13	4	120	266.667	90	1505	50	ONEDN	.
6	4.20	4	N	32	9	22	22	7	9	101	224.444	90	1930	43	PLANTON	.
7	4.20	7	N	26	11	21	28	11	3	100	222.222	90	2015	43	HALFUP	.
8	4.20	11	N	120	16	28	24	11	4	203	451.111	90	2120	43	HALFDN	.
9	4.20	19	N	26	13	33	12	11	143	238	528.889	90	2055	43	ONEDN	.
10	4.21	8	D	102	19	11	5	1	1	139	308.889	315	.	43	HALFDN	.
11	4.24	3	D	25	18	17	3	0	2	65	144.444	315	1125	46	PLANTON	.
12	4.24	8	D	0	2	3	0	1	1	7	15.556	315	1035	46	HALFDN	.
13	4.24	12	D	6	1	0	0	0	1	8	17.778	315	950	46	HALFUP	.
14	4.24	16	D	8	5	4	0	0	1	18	40.000	315	1100	46	ONEDN	.
15	4.26	1	N	128	15	6	2	1	0	152	337.778	135	1910	43	PLANTON	.
16	4.26	8	N	14	1	1	1	8	.	.	.	135	1950	43	HALFUP	.
17	4.26	12	N	12	3	4	4	0	2	25	55.556	135	2020	43	HALFDN	.
18	4.26	20	N	15	6	5	0	1	0	27	60.000	135	2055	43	ONEDN	.
19	5.02	2	N	17	2	5	2	1	4	31	68.889	45	1720	48	PLANTON	.
20	5.02	6	N	22	5	7	3	2	0	39	86.667	45	1800	48	HALFUP	.
21	5.02	10	N	33	11	4	1	3	0	52	115.556	45	1825	48	HALFDN	.
22	5.02	18	N	21	1	5	8	1	0	36	80.000	45	1900	48	ONEDN	.
23	5.08	4	N	10	1	0	3	2	0	16	35.556	90	1700	46	PLANTON	.
24	5.08	7	N	3	1	1	4	1	0	10	22.222	90	1835	46	HALFUP	.
25	5.08	11	N	18	4	0	1	1	9	33	73.333	90	1730	46	HALFDN	.
26	5.08	15	N	1	1	0	0	2	0	4	8.889	90	1815	46	ONEDN	.
27	5.10	2		.	.	.	.	.	.	.	.	.	1350	.	PLANTON	.
28	5.10	7		.	.	.	.	.	.	.	.	.	1420	.	HALFDN	.
29	5.10	11		.	.	.	.	.	.	.	.	.	1505	.	HALFDN	.
30	5.10	15		.	.	.	.	.	.	.	.	.	1445	.	ONEDN	.
31	5.12	2	N	8	9	7	0	1	0	25	55.556	270	1820	42	PLANTON	.
32	5.12	7	N	19	7	1	1	1	1	30	66.667	270	1845	42	HALFDN	.
33	5.12	11	N	74	19	10	3	3	0	109	242.222	270	1930	42	HALFUP	.
34	5.12	15	N	.	13	10	4	3	0	.	.	270	1905	42	ONEDN	.
35	5.16	2	D	149	100	50	12	1	0	312	693.333	225	1315	50	PLANTON	.
36	5.16	6	D	35	18	25	9	9	7	103	228.889	225	1415	50	HALFDN	.
37	5.16	10	D	7	3	.	7	42	0	.	.	225	1450	50	HALFUP	.
38	5.16	14	D	74	16	17	8	2	6	123	273.333	225	1355	50	ONEDN	.
39	5.18	3	N	25	10	3	3	4	1	46	102.222	45	1915	43	PLANTON	.
40	5.18	18		.	.	.	.	.	.	.	.	.	1705	.	ONEDN	.
41	5.22	2	D	7	3	4	1	4	0	19	42.222	225	1100	48	PLANTON	.
42	5.22	6	D	13	3	2	10	5	0	33	73.333	225	1125	48	HALFDN	.
43	5.22	10	D	28	7	2	8	4	0	49	108.889	225	1205	48	HALFUP	.
44	5.22	14	D	67	30	17	16	15	0	145	322.222	225	1145	48	ONEDN	.
45	5.24	3	N	18	10	4	1	2	6	41	91.111	45	1850	43	PLANTON	.
46	5.24	6	N	37	4	7	14	10	1	73	162.222	45	2005	43	HALFUP	.
47	5.24	10	N	.	2	4	3	1	0	.	.	45	2030	43	HALFDN	.
48	5.24	18	N	23	1	1	0	1	1	27	60.000	45	.	43	ONEDN	.
49	5.26	3	D	.	53	6	2	2	0	.	.	45	.	52	PLANTON	.
50	5.26	6	D	98	24	45	17	7	0	191	424.444	45	1350	52	HALFUP	.
51	5.26	10	D	78	6	12	8	5	0	109	242.222	45	1430	52	HALFDN	.
52	5.26	18	D	.	15	21	1	2	1	.	.	45	1430	52	ONEDN	.
53	5.30	3	N	31	36	28	9	6	0	110	244.444	45	1640	43	PLANTON	.
54	5.30	6	N	21	6	4	3	3	1	38	84.444	45	1805	43	HALFUP	.

(continued)

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TABLE E-1 (continued)

OBS	DATE	LOCATION	ONCODE	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	TCONC	WD	TIME	INCTIME	POSITION	X
55	5.30	10	N	36	6	4	3	3	1	53	117.778	45	1735	43	HALFDN	.
56	5.30	18	N	33	21	11	15	27	2	109	242.222	45	.	43	ONEDN	.
57	6.01	2	D	2	1	2	3	3	12	23	51.111	270	1305	46	PLANTDN	.
58	6.01	7	D	13	8	4	5	3	1	34	75.556	270	1330	46	HALFDN	.
59	6.01	11	D	0	1	0	0	0	0	1	2.222	270	1410	46	HALFUP	.
60	6.01	15	D	30	17	12	7	3	1	70	155.556	270	1350	46	ONEDN	.
61	6.05	3	N	16	4	5	3	1	0	29	64.444	45	2035	43	PLANTDN	.
62	6.05	6	N	11	0	2	0	0	0	13	28.889	45	2015	43	HALFUP	.
63	6.05	10	N	8	2	0	0	0	0	10	22.222	45	1920	43	HALFDN	.
64	6.05	18	N	.	5	3	0	0	0	.	.	45	1942	43	ONEDN	.
65	6.07	4	D	117	72	36	4	1	1	231	513.333	90	1515	49	PLANTDN	.
66	6.07	7	D	.	1	.	3	1	0	.	.	90	1410	49	HALFUP	.
67	6.07	11	D	79	20	17	7	4	1	128	284.444	90	1455	49	HALFDN	.
68	6.07	19	D	.	6	13	2	25	4	.	.	90	1430	49	ONEDN	.
69	6.09	3	N	49	27	13	7	3	1	100	222.222	0	1815	43	PLANTDN	.
70	6.09	5	N	14	6	2	2	0	0	24	53.333	0	1935	43	HALFUP	.
71	6.09	9	N.	55	16	10	6	4	.	.	.	0	1910	43	HALFDN	.
72	6.09	17	N	15	0	4	8	6	0	33	73.333	0	1845	43	ONEDN	.
73	6.13	4	D	20	11	29	4	5	0	69	153.333	90	1400	52	PLANTDN	.
74	6.13	7	D	8	2	2	1	1	0	14	31.111	90	1505	52	HALFUP	.
75	6.13	11	D	57	17	4	2	3	0	83	184.444	90	1440	52	HALFDN	.
76	6.13	19	D	7	4	7	0	1	0	19	42.222	90	1440	52	ONEDN	.
77	6.15	4	N	84	49	29	17	5	0	184	408.889	90	1925	41	PLANTDN	.
78	6.15	7	N	24	5	4	2	2	1	38	84.444	90	1820	41	HALFUP	.
79	6.15	11	N	59	20	7	6	2	2	96	213.333	90	1920	41	HALFDN	.
80	6.15	19	N	51	8	4	4	2	1	70	155.556	90	1900	41	ONEDN	.
81	6.19	2	D	9	32	3	5	1	0	50	111.111	270	920	50	PLANTDN	.
82	6.19	7	D	16	5	8	2	3	2	36	80.000	270	1015	50	HALFDN	.
83	6.19	11	D	23	13	0	1	1	1	39	86.667	270	1040	50	HALFUP	.
84	6.19	15	D	84	7	3	5	7	2	108	240.000	270	950	50	ONEDN	.
85	6.21	4	N	93	95	65	27	8	1	289	642.222	90	1840	43	PLANTDN	.
86	6.21	7	N	35	17	8	7	6	1	74	164.444	90	1835	43	HALFUP	.
87	6.21	11	N	117	25	21	5	7	1	176	391.111	90	1900	43	HALFDN	.
88	6.21	19	N	54	26	11	8	14	1	114	253.333	90	1920	43	ONEDN	.
89	6.23	1	D	96	89	56	4	2	2	249	553.333	135	1100	47	PLANTDN	.
90	6.23	8	D	39	36	15	1	1	0	92	204.444	135	1225	47	HALFUP	.
91	6.23	12	D	102	41	12	3	0	0	158	351.111	135	1135	47	HALFDN	.
92	6.23	20	D	46	5	6	17	9	0	83	184.444	135	1200	47	ONEDN	.
93	6.27	4	N	140	107	52	30	30	3	362	804.444	90	1935	43	PLANTDN	.
94	6.27	7	N	43	24	10	2	6	0	85	188.889	90	1910	43	HALFUP	.
95	6.27	11	N	75	14	6	9	9	0	113	251.111	90	1845	43	HALFDN	.
96	6.27	19	N	88	35	16	7	10	0	156	346.667	90	1820	43	ONEDN	.
97	7.03	2	N	20	.	.	3	7	1	.	.	270	1840	44	PLANTDN	.
98	7.03	7	N	17	4	9	4	2	0	36	80.000	270	1925	44	HALFDN	.
99	7.03	11	N	10	0	2	4	5	0	21	46.667	270	1950	44	HALFUP	.
100	7.03	15	N	54	.	7	4	3	1	.	.	270	1900	44	ONEDN	.
101	7.05	2	D	14	10	10	2	3	2	41	91.111	270	1145	44	PLANTDN	.
102	7.05	7	D	31	10	12	4	5	1	63	140.000	270	1205	44	HALFDN	.
103	7.07	3	N	23	19	6	0	2	0	50	111.111	45	2310	48	'PLANTDN	.
104	7.07	6	N	45	69	23	18	9	0	164	364.444	45	2250	48	HALFUP	.
105	7.07	10	N	24	4	4	0	2	0	34	75.556	43	2220	48	HALFDN	.
106	7.07	18	N	21	8	6	0	7	2	44	97.778	45	2200	48	ONEDN	.
107	7.11	4	D	33	6	47	23	7	0	116	257.778	135	1520	.	PLANTDN	.
108	7.11	8	D	93	30	57	43	6	0	229	508.889	135	1550	.	HALFUP	.

(continued)

TABLE E-1 (continued)

OBS	DATE	LOCATION	ONCODE	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	TCONC	WD	TIME	INCTIME	POSITION	X
109	7.11	12	D	8.0	1.0	11.0	2.0	0.0	0.0	22.0	48.89	135	1445	.	HALFDN	.
110	7.11	20	D	75.0	4.0	2.0	2.0	1.0	1.0	85.0	188.89	135	1425	.	ONEDN	.
111	7.13	4	N	59.0	51.0	41.0	6.0	4.0	0.0	161.0	357.78	90	2015	44	PLANTON	.
112	7.13	7	N	18.0	3.0	0.0	0.0	2.0	0.0	23.0	51.11	90	1815	44	HALFUP	.
113	7.13	11	N	35.0	9.0	2.0	4.0	14.0	2.0	66.0	146.67	90	1905	44	HALFDN	.
114	7.13	19	N	38.0	18.0	6.0	2.0	11.0	0.0	75.0	166.67	90	1840	44	ONEDN	.
115	7.17	1	D	46.0	34.0	29.0	16.0	6.0	1.0	136.0	302.22	225	1255	51	PLANTON	.
116	7.17	6	D	15.0	1.0	0.0	2.0	1.0	0.0	19.0	42.22	225	1130	51	HALFDN	.
117	7.17	10	D	5.0	4.0	0.0	.	2.0	1.0	.	.	225	1108	51	HALFUP	.
118	7.17	14	D	0.0	0.0	0.0	3.0	0.0	0.0	3.0	6.67	225	1150	51	ONEDN	.
119	7.19	2	N	9.0	6.0	16.0	36.0	21.0	11.0	99.0	220.00	225	1745	.	PLANTON	.
120	7.19	6	N	35.0	24.0	25.0	21.0	12.0	5.0	122.0	271.11	225	1805	.	HALFDN	.
121	7.19	10	N	9.0	6.0	7.0	37.0	11.0	4.0	74.0	164.44	225	1900	.	HALFUP	.
122	7.19	14	N	280.0	70.0	86.0	72.0	30.0	9.0	547.0	1215.56	225	1825	.	ONEDN	.
123	7.25	3	N	241.0	180.0	289.0	29.0	7.0	0.0	746.0	1657.78	0	.	44	PLANTON	.
124	7.25	5	N	10.0	2.0	1.0	3.0	23.0	3.0	42.0	93.33	0	1925	44	HALFUP	.
125	7.25	9	N	18.0	5.0	4.0	2.0	1.0	1.0	31.0	68.89	0	1945	44	HALFDN	.
126	7.25	17	N	24.0	.	1.0	1.0	6.0	0.0	.	.	0	2005	44	ONEDN	.
127	7.27	4	D	45.0	86.0	43.0	19.0	11.0	9.0	213.0	473.33	90	1750	44	PLANTON	.
128	7.27	7	D	14.0	9.0	10.0	7.0	7.0	0.0	47.0	104.44	90	1630	44	HALFUP	.
129	7.27	11	D	64.0	18.0	22.0	24.0	10.0	4.0	142.0	315.56	90	1410	44	HALFDN	.
130	7.27	19	D	23.0	18.0	19.0	9.0	8.0	2.0	79.0	175.56	90	1320	44	ONEDN	.
131	7.31	2	N	24.0	45.0	7.0	6.0	19.0	.	.	.	270	1925	43	PLANTON	.
132	7.31	7	N	41.0	8.0	23.0	2.0	9.0	5.0	88.0	195.56	270	1625	43	HALFDN	.
133	7.31	11	N	40.0	.	13.0	3.0	5.0	2.0	.	.	270	1655	43	HALFUP	.
134	7.31	15	N	48.0	16.0	13.0	61.0	73.0	5.0	216.0	480.00	270	1800	43	ONEDN	.
135	8.04	3	N	2.0	2.0	8.0	2.0	0.0	0.0	14.0	31.11	45	2320	.	PLANTON	.
136	8.04	6	N	50.0	7.0	19.0	1.0	3.0	2.0	82.0	182.22	45	2225	.	HALFUP	.
137	8.04	10	N	2.0	1.0	0.0	3.0	1.0	0.0	7.0	15.56	45	2305	.	HALFDN	.
138	8.04	18	N	6.0	3.0	8.0	3.0	0.0	0.0	20.0	44.44	45	2245	.	ONEDN	.
139	8.08	2	D	46.5	37.0	17.5	7.5	.	1.0	.	.	270	1600	52	PLANTON	.
140	8.08	7	D	.	7.5	5.5	55.0	3.0	1.5	.	.	270	1305	52	HALFDN	.
141	8.08	11	D	19.0	6.5	2.0	8.0	6.0	0.0	41.5	92.22	270	1325	52	HALFUP	.
142	8.08	15	D	13.0	7.5	3.0	8.5	.	0.0	.	.	270	1245	52	ONEDN	.
143	8.10	3	N	144.0	58.0	23.0	12.0	7.0	0.0	244.0	542.22	0	2015	44	PLANTON	.
144	8.10	5	N	.	.	31.0	1.0	8.0	0.0	.	.	0	1900	44	HALFUP	.
145	8.10	9	N	48.0	16.0	23.0	7.0	7.0	1.0	102.0	226.67	0	1940	44	HALFDN	.
146	8.10	17	N	172.0	87.0	22.0	11.0	12.0	1.0	305.0	677.78	0	1920	44	ONEDN	.
147	8.14	3	D	112.0	96.5	179.5	24.0	7.5	0.5	420.0	933.33	45	940	54	PLANTON	.
148	8.14	6	D	2.0	3.0	1.0	1.0	2.0	1.0	10.0	22.22	45	835	54	HALFUP	.
149	8.14	10	D	13.0	5.5	3.5	4.0	0.0	2.0	28.0	62.22	45	900	54	HALFDN	.
150	8.14	18	D	51.5	2.5	26.5	14.0	2.0	0.0	96.5	214.44	45	920	54	ONEDN	.
151	8.16	3	N	28.0	27.0	40.0	3.0	6.0	3.0	107.0	237.78	0	1905	44	PLANTON	.
152	8.16	5	N	15.0	3.0	1.0	4.0	2.0	1.0	26.0	57.78	0	1800	44	HALFUP	.
153	8.16	9	N	183.0	90.0	32.0	13.0	2.0	1.0	321.0	713.33	0	1850	44	HALFDN	.
154	8.16	17	N	11.0	7.0	2.0	1.0	1.0	0.0	22.0	48.89	0	1825	44	ONEDN	.
155	8.18	3	D	71.0	78.0	55.0	16.0	4.0	0.0	224.0	497.78	45	1450	51	PLANTON	.
156	8.18	6	D	31.0	21.0	11.0	7.0	1.0	0.0	71.0	157.78	45	1405	51	HALFUP	.
157	8.18	10	D	23.0	12.0	9.0	9.0	5.0	0.0	58.0	128.89	45	1340	51	HALFDN	.
158	8.18	18	D	34.0	12.0	9.0	4.0	27.0	7.0	93.0	206.67	45	1315	51	ONEDN	.
159	8.22	2	N	82.0	126.0	59.0	49.0	119.0	4.0	439.0	975.56	225	1910	.	PLANTON	.
160	8.22	6	N	.	49.5	28.5	22.5	7.0	0.0	.	.	225	1825	.	HALFDN	.
161	8.22	10	N	.	13.0	12.0	14.0	39.5	.	.	.	225	1850	.	HALFUP	.
162	8.22	14	N	268.0	125.0	103.0	33.5	13.0	1.0	543.5	1207.78	225	1800	.	ONEDN	.

(continued)

TABLE E-1 (continued)

OBS	DATE	LOCATION	DNCODE	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	TCONC	WD	TIME	INCTIME	POSITION	X
163	8.24	3	D	38.0	55.5	29.5	3.5	3.5	0.0	130.0	288.89	45	1225	48	PLANTON	.
164	8.24	6	D	14.5	4.0	1.5	1.0	1.0	2.0	24.0	53.33	45	1120	48	HALFUP	.
165	8.24	10	D	18.5	4.5	2.0	0.5	1.0	0.0	26.5	58.89	45	1205	48	HALFDN	.
166	8.24	18	D	12.5	3.5	1.5	0.0	3.5	0.0	21.0	46.67	45	1145	48	ONEDN	.
167	8.30	3	D	40.5	24.0	11.5	7.0	2.0	1.5	86.5	192.22	315	1415	52	PLANTON	.
168	8.30	8	D	20.0	8.5	8.0	5.0	2.5	49.0	93.0	206.67	315	1340	52	HALFDN	.
169	8.30	11	D	30.0	11.0	0.5	0.0	7.0	1.0	49.5	110.00	315	1300	52	HALFUP	.
170	8.30	16	D	29.0	7.5	1.5	4.0	14.0	0.5	56.5	125.56	315	1320	52	ONEDN	.
171	9.01	3	N	26.0	19.0	14.0	7.0	0.0	0.0	66.0	146.67	315	2152	44	PLANTON	.
172	9.01	8	N	11.0	11.0	6.0	3.0	1.0	1.0	33.0	73.33	315	1935	44	HALFDN	.
173	9.01	12	N	19.0	2.0	4.0	.	0.0	1.0	.	.	315	2030	44	HALFUP	.
174	9.01	16	N	11.0	6.0	0.0	1.0	0.0	1.0	19.0	42.22	315	2005	44	ONEDN	.
175	9.05	3	D	17.5	10.5	36.5	30.0	2.0	0.0	96.5	214.44	315	905	49	PLANTON	.
176	9.05	8	D	12.0	1.0	0.0	1.0	4.5	0.5	19.0	42.22	315	800	49	HALFDN	.
177	9.05	11	D	15.5	5.5	1.5	5.5	5.5	1.5	35.0	77.78	315	840	49	HALFUP	.
178	9.05	16	D	1.0	2.5	1.0	3.5	0.0	1.0	9.0	20.00	315	820	49	ONEDN	.
179	9.07	3	N	50.0	35.0	.	10.0	3.0	2.0	.	.	0	2025	44	PLANTON	.
180	9.07	5	N	11.0	10.0	3.0	4.0	10.0	1.0	39.0	86.67	0	2010	44	HALFUP	.
181	9.07	9	N	33.0	21.0	9.0	14.0	16.0	5.0	98.0	217.78	0	1945	44	HALFDN	.
182	9.07	17	N	48.0	17.0	2.0	.	5.0	1.0	.	.	0	1925	44	ONEDN	.
183	9.11	1	D	194.0	220.0	213.0	89.0	51.0	2.0	769.0	1708.89	135	1810	49	PLANTON	.
184	9.11	8	D	103.0	24.0	15.0	13.0	31.0	4.0	190.0	422.22	135	1715	49	HALFUP	.
185	9.11	12	D	125.0	37.0	18.0	15.0	12.0	5.0	212.0	471.11	135	1735	49	HALFDN	.
186	9.11	20	D	.	71.0	39.0	42.0	77.0	10.0	.	.	135	1755	49	ONEDN	.
187	9.13	3	N	58.0	90.0	183.5	36.5	6.0	2.5	376.5	836.67	0	1910	43	PLANTON	.
188	9.13	5	N	12.0	2.0	7.5	1.5	9.0	3.0	35.0	77.78	0	1845	43	HALFUP	.
189	9.13	9	N	32.5	20.5	101.5	4.0	4.5	1.0	164.0	364.44	0	1800	43	HALFDN	.
190	9.13	17	N	13.5	1.5	9.0	3.5	2.0	0.5	30.0	66.67	0	1820	43	ONEDN	.
191	9.19	2	N	46.0	33.0	40.0	8.0	3.0	0.5	130.5	290.00	270	1910	50	PLANTON	.
192	9.19	7	N	40.5	19.0	3.0	5.5	1.0	0.0	69.0	153.33	270	1845	50	HALFDN	.
193	9.19	11	N	39.0	23.5	12.5	3.0	1.5	0.0	79.5	176.67	270	1800	50	HALFUP	.
194	9.19	15	N	51.0	2.0	7.0	4.0	3.0	4.0	71.0	157.78	270	1820	50	ONEDN	.
195	9.21	3	D	44.0	42.5	24.5	8.0	2.5	0.0	121.5	270.00	315	1427	43	PLANTON	.
196	9.21	8	D	112.0	20.0	13.0	4.0	1.0	1.0	151.0	335.56	315	1345	43	HALFDN	.
197	9.21	12	D	26.5	15.5	3.0	1.0	0.0	0.0	46.0	102.22	315	1225	43	HALFUP	.
198	9.21	16	D	25.5	8.0	4.5	0.0	0.0	0.0	38.0	84.44	315	1308	43	ONEDN	.
199	9.25	1	N	50.0	35.0	58.5	15.0	7.0	1.0	166.5	370.00	180	2008	44	PLANTON	.
200	9.25	5	N	82.0	39.5	8.5	9.5	9.0	1.0	149.5	332.22	180	1840	44	HALFDN	.
201	9.25	9	N	60.0	.	3.5	9.5	.	0.0	.	.	180	1920	44	HALFUP	.
202	9.25	13	N	92.5	19.0	8.5	7.0	10.0	2.0	139.0	308.89	180	1805	44	ONEDN	.
203	9.27	2	D	86.0	139.5	22.5	8.0	5.0	0.0	261.0	580.00	270	1732	47	PLANTON	.
204	9.27	7	D	71.5	24.0	17.0	10.0	4.0	0.0	120.5	261.11	270	1657	47	HALFDN	.
205	9.27	11	D	34.5	14.0	5.5	7.0	5.0	1.0	67.0	148.89	270	1820	47	HALFUP	.
206	9.27	15	D	46.0	13.0	.	9.5	0.0	0.0	.	.	270	1620	47	ONEDN	.
207	9.29	1	N	99.5	74.0	46.5	4.0	3.0	0.0	227.0	504.44	180	2055	44	PLANTON	.
208	9.29	5	N	75.5	28.0	18.5	7.0	14.5	0.0	143.5	318.89	180	2015	44	HALFDN	.
209	9.29	9	N	69.0	30.5	18.0	8.0	14.5	0.0	140.0	311.11	180	1900	44	HALFUP	.
210	9.29	13	N	.	.	.	.	.	.	.	.	180	1940	.	ONEDN	.
211	10.04	2	D	123.5	116.5	72.5	22.0	2.0	0.0	336.5	747.78	270	1220	43	PLANTON	.
212	10.04	7	D	31.0	23.5	4.0	3.0	14.0	0.0	75.5	167.78	270	1103	43	HALFDN	.
213	10.04	11	D	25.0	2.5	3.5	1.0	1.5	2.5	36.0	80.00	270	1140	43	HALFUP	.
214	10.04	15	D	33.5	22.5	6.5	5.0	2.5	3.0	73.0	162.22	270	1028	43	ONEDN	.
215	10.05	2	N	62.5	59.0	29.0	12.5	15.5	0.0	178.5	396.67	270	1830	44	PLANTON	.
216	10.05	7	N	70.5	47.0	23.5	7.0	15.0	1.0	170.0	377.78	270	1925	44	HALFDN	.

(continued)

TABLE E-1 (continued)

OBS	DATE	LOCATION	ENCODE	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	TCONC	WD	TIME	INCTIME	POSITION	X
217	10.05	11	N	63.0	28.0	13.5	7.5	7.0	2.0	121.0	268.889	270	2040	44	HALFUP	.
218	10.05	15	N	44.0	16.0	12.5	12.0	42.5	5.0	132.0	293.333	270	2000	44	ONEDN	.
219	10.09	2	D	108.5	120.0	65.0	39.0	10.0	0.0	342.5	761.111	270	1652	52	PLANTON	.
220	10.09	7	D	20.5	.	8.0	0.0	6.5	2.5	.	.	270	1445	52	HALFDN	.
221	10.09	11	D	8.0	3.0	0.5	0.5	1.0	0.0	13.0	28.889	270	1525	52	HALFUP	.
222	10.09	15	D	37.5	15.5	18.5	72.0	80.5	.	.	.	270	1400	52	ONEDN	.
223	10.11	2	N	82.0	160.0	76.0	35.5	12.5	1.0	369.0	820.000	270	2030	45	PLANTON	.
224	10.11	7	N	69.0	35.0	16.0	21.0	10.5	4.0	155.5	345.556	270	1950	45	HALFDN	.
225	10.11	11	N	56.0	24.0	29.0	3.0	8.5	52.0	172.5	383.333	270	1820	45	HALFUP	.
226	10.11	15	N	65.0	42.5	19.0	5.0	4.0	2.0	137.5	305.556	270	1900	45	ONEDN	.
227	10.13	2	D	88.5	86.5	58.0	25.5	1.0	0.0	259.5	576.667	225	1740	43	PLANTON	.
228	10.13	6	D	112.0	32.5	52.5	15.5	3.0	1.0	216.5	481.111	225	1635	43	HALFDN	.
229	10.13	10	D	91.5	10.0	9.5	1.0	2.0	0.0	114.0	253.333	225	1710	43	HALFUP	.
230	10.13	14	D	215.0	97.5	29.0	5.0	0.0	0.0	346.5	770.000	225	1600	43	ONEDN	.
231	10.17	2	N	94.0	57.0	55.0	13.5	20.5	3.0	243.0	540.000	225	1820	46	PLANTON	.
232	10.17	6	N	36.5	57.0	22.0	8.0	9.5	3.5	136.5	303.333	225	1935	46	HALFDN	.
233	10.17	10	N	59.0	53.0	24.5	3.0	17.0	0.0	156.5	347.778	225	2010	46	HALFUP	.
234	10.17	14	N	141.0	104.5	48.5	13.5	20.5	0.5	328.5	730.000	225	1900	46	ONEDN	.
235	10.19	3	D	42.5	60.5	66.0	12.5	10.0	0.0	191.5	425.556	315	1215	45	PLANTON	.
236	10.19	8	D	68.5	13.0	84.0	18.0	0.0	1.0	184.5	410.000	315	1100	45	HALFDN	.
237	10.19	12	D	10.5	2.0	2.5	2.0	1.0	1.5	19.5	43.333	315	1015	45	HALFUP	.
238	10.19	16	D	11.0	6.0	0.0	0.0	3.0	0.5	20.5	45.556	315	1140	45	ONEDN	.
239	10.23	4	N	27.5	41.0	36.5	10.0	2.0	1.0	118.0	262.222	90	2015	44	PLANTON	.
240	10.23	7	N	3.0	2.0	1.0	1.5	0.0	0.0	7.5	16.667	90	1820	44	HALFUP	.
241	10.23	11	N	11.0	5.0	2.0	2.0	0.0	0.0	20.0	44.444	90	1940	44	HALFDN	.
242	10.23	19	N	10.0	6.0	0.0	0.0	0.0	0.0	16.0	35.556	90	1905	44	ONEDN	.
243	10.25	1	D	1.5	5.0	22.5	1.0	0.5	0.0	30.5	67.778	180	1100	51	PLANTON	.
244	10.25	5	D	4.5	2.0	3.0	5.0	0.0	0.0	14.5	32.222	180	1215	51	HALFDN	.
245	10.25	9	D	14.5	2.0	4.0	7.0	3.0	0.5	31.0	68.889	180	1255	51	HALFUP	.
246	10.25	13	D	3.5	3.5	5.0	2.0	1.0	0.0	15.0	33.333	180	1140	51	ONEDN	.
247	10.27	4	N	11.5	9.5	18.0	2.0	1.0	1.5	43.5	96.667	90	2030	44	PLANTON	.
248	10.27	7	N	12.0	6.0	14.5	10.5	0.0	0.0	43.0	95.556	90	1835	44	HALFUP	.
249	10.27	11	N	18.0	4.5	1.0	0.5	1.5	0.0	25.5	56.667	90	1913	44	HALFDN	.
250	10.27	19	N	8.5	2.5	0.0	0.0	0.5	0.0	11.5	25.556	90	1955	44	ONEDN	.
251	10.31	1	D	2.5	2.0	4.5	2.0	0.0	0.0	11.0	24.444	180	1000	45	PLANTON	.
252	10.31	5	D	59.5	8.0	5.5	2.0	13.5	0.0	88.5	196.667	180	1040	45	HALFDN	.
253	10.31	9	D	69.5	18.5	10.0	5.0	3.0	0.0	106.0	235.556	180	1200	45	HALFUP	.
254	10.31	13	D	30.0	14.0	9.5	3.5	0.0	0.0	57.0	126.667	180	1120	45	ONEDN	.
255	11.02	1	N	50.0	48.0	57.0	22.0	4.5	3.0	184.5	410.000	180	2025	48	PLANTON	.
256	11.02	5	N	111.5	49.5	22.5	16.5	15.0	0.0	215.0	477.778	180	1905	48	HALFDN	.
257	11.02	9	N	89.0	30.0	6.0	1.5	3.0	0.5	130.0	288.889	180	1825	48	HALFUP	.
258	11.02	13	N	85.0	24.5	19.0	4.0	3.5	0.0	136.0	302.222	180	1945	48	ONEDN	.
259	11.06	3	D	18.0	6.0	14.5	3.0	3.5	0.0	45.0	100.000	0	1045	46	PLANTON	.
260	11.06	5	D	4.0	5.5	0.0	3.0	0.0	0.0	12.5	27.778	0	1005	46	HALFUP	.
261	11.06	9	D	1.0	3.0	1.5	2.0	0.0	0.0	7.5	16.667	0	850	46	HALFDN	.
262	11.06	17	D	2.5	1.5	2.0	0.0	1.0	0.0	7.0	15.556	0	925	46	ONEDN	.
263	11.08	2	N	62.0	17.0	1.0	1.0	1.0	0.0	82.0	182.222	225	1845	45	PLANTON	.
264	11.08	6	N	33.0	1.5	1.5	0.5	2.0	0.0	38.5	85.556	225	2010	45	HALFDN	.
265	11.08	10	N	20.5	3.0	2.0	0.5	0.0	0.0	26.0	57.778	225	2045	45	HALFUP	.
266	11.08	14	N	241.5	39.0	21.5	0.5	0.0	0.0	302.5	672.222	225	1930	45	ONEDN	.
267	11.10	1	D	14.5	11.5	14.0	8.5	1.0	0.0	49.5	110.000	225	1130	53	PLANTON	.
268	11.10	6	D	7.0	2.0	4.5	5.5	0.0	0.0	19.0	42.222	225	1050	53	HALFDN	.
269	11.10	10	D	1.5	2.0	1.5	4.0	6.0	0.0	15.0	33.333	225	1035	53	HALFUP	.
270	11.10	14	D	5.0	1.0	2.0	1.0	0.0	0.0	9.0	20.000	225	1110	53	ONEDN	.

(continued)

TABLE E-1 (continued)

OBS	DATE	LOCATION	DNCODE	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	TCONC	WD	TIME	INCTIME	POSITION	X
271	11.14	1	N	47.5	34.0	8.0	5.0	4.5	0.0	99.0	220.000	180	1800	43	PLANTON	.
272	11.14	5	N	80.0	13.5	12.5	4.0	3.0	0.0	113.0	251.111	180	1935	43	HALFDN	.
273	11.14	9	N	70.5	19.5	7.5	4.0	1.5	0.0	103.0	228.889	180	2025	43	HALFUP	.
274	11.14	13	N	57.0	20.5	6.5	4.0	1.5	0.0	89.5	198.889	180	1900	43	ONEDN	.
275	11.16	2	D	100.0	86.0	43.5	9.0	1.0	0.0	239.5	532.222	270	1230	43	PLANTON	.
276	11.16	7	D	50.0	14.0	8.5	2.5	1.0	0.0	76.0	168.889	270	1150	43	HALFDN	.
277	11.16	11	D	30.0	12.5	4.0	4.0	10.0	1.0	61.5	136.667	270	1350	43	HALFUP	.
278	11.16	15	D	53.5	11.0	5.0	4.0	6.0	0.0	79.5	176.667	270	1310	43	ONEDN	.
279	11.20	1	N	40.0	116.0	114.0	42.0	26.5	2.5	341.0	757.778	180	1735	45	PLANTON	.
280	11.20	5	N	.	.	.	.	1.0	0.0	.	.	180	1850	45	HALFDN	.
281	11.20	9	N	0.0	.	2.0	7.5	0.5	9.5	.	.	180	1805	45	HALFUP	.
282	11.20	13	N	5.5	1.0	5.5	6.5	1.0	0.0	19.5	43.333	180	1926	45	ONEDN	.
283	11.22	4	N	28.5	33.5	76.0	25.5	0.0	.	.	.	90	1920	36	PLANTON	.
284	11.22	7	N	4.0	7.0	65.0	16.5	1.0	32.0	125.5	278.889	90	1830	36	HALFUP	.
285	11.22	11	N	9.5	7.0	22.0	3.0	1.0	0.0	42.5	94.444	90	1740	36	HALFDN	.
286	11.22	19	N	3.0	2.0	1.0	3.0	4.0	6.5	19.5	43.333	90	1715	36	ONEDN	.
287	11.24	2	D	20.0	24.5	9.0	8.0	1.0	0.0	62.5	138.889	270	1050	46	PLANTON	.
288	11.24	7	D	5.0	3.5	2.5	0.0	0.0	0.0	11.0	24.444	270	930	46	HALFDN	.
289	11.24	11	D	1.0	0.0	0.0	0.0	0.0	0.0	1.0	2.222	270	1015	46	HALFUP	.
290	11.24	15	D	1.0	0.0	0.0	0.0	4.5	0.0	5.5	12.222	270	935	46	ONEDN	.
291	11.28	2	N	18.5	18.5	12.0	2.0	0.0	2.5	53.5	118.889	270	1700	48	PLANTON	.
292	11.28	7	N	4.0	2.0	1.5	0.5	0.0	0.0	8.0	17.778	270	1745	48	HALFDN	.
293	11.28	11	N	1.0	2.5	1.0	0.0	0.0	0.5	5.0	11.111	270	1905	48	HALFUP	.
294	11.28	15	N	1.5	1.0	3.0	1.0	1.5	0.0	8.0	17.778	270	1830	48	ONEDN	.
295	11.30	3	N	30.5	28.5	34.0	16.0	15.5	0.0	124.5	276.667	0	1925	45	PLANTON	.
296	11.30	5	N	1.0	0.5	2.0	4.0	0.0	0.5	8.0	17.778	0	1730	45	HALFUP	.
297	11.30	9	N	200.5	0.5	1.0	0.0	0.0	2.0	204.0	453.333	0	1810	45	HALFDN	.
298	11.30	17	N	2.0	68.5	0.0	0.5	0.5	0.5	72.0	160.000	0	1845	45	ONEDN	.

TABLE E-2. TOTAL COLIFORM PARTICLES IN AIR DATA SET

OBS	DATE	DNCODE	LOCATION	PUMP	INCTIME	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	CONC	WD	RH	TEMP	TIME
1	9.13	N	3	99	22	6	4	2	2	1	0	15	33.3	0	95	59	1910
2	9.13	N	5	97	22	0	0	0	0	0	0	0	0.0	0	83	62	1845
3	9.13	N	9	97	22	0	0	0	0	0	0	0	0.0	0	79	63	1800
4	9.13	N	17	99	22	0	0	0	0	0	0	0	0.0	0	83	62	1820
5	9.19	N	2	99	23	0	0	0	0	0	0	0	0.0	270	79	63	1910
6	9.19	N	7	99	23	0	2	1	0	0	0	3	6.7	270	74	64	1845
7	9.19	N	11	99	23	2	1	1	0	0	0	4	8.9	270	74	65	1800
8	9.19	N	15	99	23	2	0	0	0	0	0	2	4.4	270	74	64	1820
9	9.21	D	3	99	26	12	5	2	0	0	0	19	21.1	315	83	61	1427
10	9.21	D	8	99	26	2	0	0	0	0	0	2	2.2	315	65	65	1345
11	9.21	D	12	99	26	0	1	0	1	0	0	2	2.2	315	78	61	1225
12	9.21	D	16	99	26	0	0	0	0	0	0	0	0.0	315	70	64	1305
13	9.25	N	1	97	24	1	0	0	0	0	0	1	1.1	180	58	.	2008
14	9.25	N	5	97	24	1	0	0	0	0	0	1	1.1	160	53	71	1840
15	9.25	N	9	97	24	2	0	0	0	0	0	2	2.2	180	54	74	1920
16	9.25	N	13	97	24	0	0	0	0	0	0	0	0.0	180	41	79	1805
17	9.27	D	2	99	22	2	1	0	0	0	0	3	3.3	270	70	64	1732
18	9.27	D	7	99	22	0	0	0	0	0	0	0	0.0	270	65	64	1657
19	9.27	D	11	99	22	1	0	0	0	0	0	1	2.2	270	74	62	1820
20	9.27	D	15	99	22	1	0	0	0	0	0	0	1.1	270	74	66	1620
21	9.29	N	1	99	24	0	0	0	0	0	0	0	0.0	180	66	65	2055
22	9.29	N	5	99	24	1	0	0	0	0	0	1	1.1	160	70	.	2015
23	9.29	N	9	99	24	0	0	0	0	0	0	0	0.0	180	59	.	1830
24	9.29	N	13	99	24	1	0	0	0	0	0	1	1.1	180	61	.	1930
25	10.04	D	2	97	24	1	1	0	0	0	0	2	2.2	270	50	65	1220
26	10.04	D	7	97	24	0	0	0	0	0	0	0	0.0	270	50	65	1103
27	10.04	D	11	97	24	0	0	0	0	0	0	0	0.0	270	47	67	1140
28	10.04	D	15	97	24	0	0	0	0	0	0	0	0.0	270	50	61	1028
29	10.05	N	2	97	23	1	1	0	0	0	0	2	2.2	270	38	59	1830
30	10.05	N	7	97	23	0	0	0	0	0	0	0	0.0	270	36	61	1925
31	10.05	N	11	97	23	2	0	0	0	0	0	2	2.2	270	54	54	2040
32	10.09	D	2	95	22	3	2	1	0	0	0	6	6.7	270	56	57	1652
33	10.09	D	7	95	22	0	0	0	0	0	0	0	0.0	270	60	55	1445
34	10.09	D	11	95	22	1	0	0	0	0	0	1	1.1	270	43	60	1525
35	10.09	D	15	95	22	1	0	0	0	0	0	1	1.1	270	60	55	1400
36	10.11	N	2	98	25	1	2	4	1	0	0	8	8.9	270	66	47	2030
37	10.11	N	7	98	25	1	2	0	0	0	0	3	3.3	270	59	48	1950
38	10.11	N	11	98	25	1	1	0	0	0	0	2	2.2	270	66	.	1820
39	10.11	N	15	98	25	2	0	0	0	0	0	2	2.2	270	66	47	1900
40	10.13	D	2	95	25	5	3	1	0	0	0	9	10.0	225	45	57	1740
41	10.13	D	6	95	25	0	1	0	0	0	0	1	1.1	225	35	60	1635
42	10.13	D	10	95	25	0	0	0	0	0	0	0	0.0	225	48	59	1710
43	10.13	D	14	95	25	2	0	0	0	0	0	2	2.2	225	39	60	1600
44	10.17	N	2	98	24	1	2	0	0	0	0	3	3.3	225	51	61	1820
45	10.17	N	6	98	24	1	4	1	0	0	0	6	6.7	225	52	58	1935
46	10.17	N	10	98	24	1	0	0	0	0	0	1	1.1	225	56	56	2010
47	10.17	N	14	98	24	0	0	0	0	0	0	0	0.0	225	59	60	1900
48	10.19	D	3	98	23	1	1	1	0	0	0	3	3.3	315	70	54	1215
49	10.19	D	8	98	23	0	0	0	0	0	0	0	0.0	315	81	51	1100
50	10.19	D	12	98	23	1	0	0	0	0	0	1	1.1	315	65	.	1015
51	10.19	D	16	98	23	0	0	0	0	0	0	0	0.0	315	75	53	1140
52	10.23	N	4	95	24	9	0	7	4	1	0	21	23.3	90	73	.	2015
53	10.23	N	7	95	24	0	0	0	0	0	0	0	0.0	90	75	.	1820
54	10.23	N	11	95	24	0	0	0	0	0	0	0	0.0	90	80	.	1940

(continued)

TABLE E-2 (continued)

OBS	DATE	UNCODE	LOCATION	PUMP	INCTIME	PC1	PC2	PC3	PC4	PC5	PC6	TOTALPC	CONC	WD	RH	TEMP	TIME
55	10.23	N	19	95	24	0	0	1	0	0	0	1	1.1	90	80	.	1905
56	10.25	D	1	98	23	6	3	1	0	0	0	10	11.1	180	89	61	1100
57	10.25	D	5	98	23	1	0	0	0	.	0	.	.	180	89	61	1215
58	10.25	D	9	98	23	1	0	0	0	0	0	1	1.1	180	64	62	1255
59	10.25	D	13	98	23	0	0	0	0	0	0	0	0.0	180	69	60	1110
60	10.31	D	1	98	25	0	1	0	0	0	1	2	2.2	180	78	60	1000
61	10.31	D	5	98	25	0	0	0	0	0	0	0	0.0	180	74	64	1040
62	10.31	D	9	98	25	1	0	1	0	0	0	2	2.2	160	79	64	1200
63	10.31	D	13	98	25	6	3	0	0	0	0	9	10.0	180	74	63	1120
64	11.02	N	1	98	24	1	0	0	0	0	0	1	1.1	180	55	64	2025
65	11.02	N	5	98	24	2	1	1	0	0	0	4	4.4	180	84	65	1905
66	11.02	N	9	98	24	0	0	0	0	0	0	0	0.0	160	66	67	1825
67	11.02	N	13	98	24	0	0	0	0	0	0	0	0.0	180	69	62	1915
68	11.06	D	3	95	22	3	1	0	0	0	0	4	4.4	0	89	.	1045
69	11.06	D	5	95	22	0	0	0	0	0	0	0	0.0	0	89	.	1035
70	11.06	D	9	95	22	1	0	0	0	0	0	1	1.1	0	89	.	850
71	11.06	D	17	95	22	0	0	0	0	0	0	0	0.0	0	89	55	925
72	11.08	N	2	98	22	0	0	0	0	0	0	0	0.0	225	95	62	1645
73	11.08	N	6	98	23	0	0	0	0	0	0	0	0.0	225	95	60	2010
74	11.08	N	10	98	23	0	0	0	0	0	0	0	0.0	225	95	60	2045
75	11.08	N	14	98	23	0	0	0	0	0	0	0	0.0	225	95	61	1930
76	11.14	N	1	98	.	1	0	0	0	0	0	1	1.1	160	74	.	1800
77	11.14	N	5	98	.	0	0	0	0	0	0	0	0.0	160	60	.	1935
78	11.14	N	9	98	.	0	1	0	0	0	0	1	1.1	160	74	50	2025
79	11.14	N	13	98	.	.	.	0	0	0	0	.	.	180	74	.	1900
80	11.16	D	2	95	22	2	0	1	0	0	0	3	3.3	270	56	.	1230
81	11.16	D	7	95	22	1	0	0	0	0	0	1	1.1	270	49	.	1150
82	11.16	D	11	95	22	1	0	0	0	0	0	1	1.1	270	42	.	1350
83	11.16	D	15	95	22	0	0	0	0	0	0	0	0.0	270	49	.	1310
84	11.20	N	1	98	23	5	2	2	0	1	0	10	11.1	180	77	.	1735
85	11.20	N	5	95	23	0	0	0	0	0	0	0	0.0	180	74	.	1850
86	11.20	N	9	95	23	0	0	0	0	0	0	0	0.0	180	68	.	1805
87	11.20	N	13	95	23	0	1	0	0	0	0	1	1.1	180	58	.	1926
88	11.22	N	4	95	23	1	0	0	0	0	0	1	1.1	90	41	.	1920
89	11.22	N	7	95	23	0	0	0	0	0	0	0	0.0	90	76	.	1840
90	11.22	N	11	95	23	0	0	0	0	0	0	0	0.0	90	83	.	1740
91	11.22	N	19	95	23	0	0	0	0	0	0	0	0.0	90	75	.	1715
92	11.24	D	2	95	24	0	0	0	0	0	0	0	0.0	270	75	.	1050
93	11.24	D	7	95	24	0	0	0	0	0	0	0	0.0	270	80	.	900
94	11.24	D	11	95	24	0	0	0	0	0	0	0	0.0	270	65	.	1015
95	11.24	D	15	95	24	0	0	0	0	0	0	0	0.0	270	63	.	935
96	11.28	N	2	98	24	0	0	1	0	0	0	1	1.1	270	90	.	1700
97	11.28	N	7	98	24	0	0	0	0	0	0	0	0.0	270	49	.	1745
98	11.28	N	11	98	24	0	0	0	0	0	0	0	0.0	270	90	.	1905
99	11.28	N	15	98	24	0	0	0	0	0	0	0	0.0	270	80	.	1930
100	11.30	N	3	98	22	6	6	4	2	3	0	21	23.3	0	95	.	1925
101	11.30	N	5	98	22	0	0	0	0	0	1	1	1.1	0	89	.	1730
102	11.30	N	9	98	22	0	0	0	0	0	0	0	0.0	0	86	45	1810
103	11.30	N	17	98	22	0	0	0	0	0	0	0	0.0	0	88	.	1645

TABLE E-3. VIABLE SEWAGE DATA SET

OBS	DATE	DNCODE	LOCATION	TVIAB	TCOLI	FCOLI	TIME
1	4.13	D	3	.	8.8	14.3	1000
2	4.14	D	1	.	34.5	19.0	1120
3	4.18	D	1	220.0	32.0	86.8	1430
4	4.20	N	1	319.8	54.5	34.5	1930
5	4.24	D	1	73.4	45.5	56.5	1000
6	4.26	N	1	114.6	47.5	0.1	1900
7	5.02	N	3	58.0	54.0	53.0	1700
8	5.08	N	1	56.5	44.0	71.4	.
9	5.10	D	1	66.5	36.0	29.5	1330
10	5.12	N	1	4250.0	73.0	56.8	1815
11	5.16	D	1	100.0	29.0	46.5	.
12	5.18	N	1	655.0	370.0	245.0	1915
13	5.22	D	1	33.5	8.9	16.4	1050
14	5.24	N	1	8.0	12.6	92.7	1915
15	5.26	D	1	3.8	15.2	35.5	1330
16	5.30	N	1	19.4	8.7	19.0	1630
17	6.01	D	1	6.5	10.3	27.0	1300
18	6.05	N	1	12.0	13.6	32.5	2045
19	6.07	D	1	46.0	41.0	47.0	1545
20	6.09	N	1	4.9	5.7	10.2	1800
21	6.13	D	1	5.6	7.6	15.0	1525
22	6.15	N	1	15.0	23.0	41.5	1950
23	6.19	D	1	13.9	18.4	51.5	910
24	6.21	N	1	14.2	40.5	119.1	1925
25	6.23	D	1	67.5	15.5	47.0	1115
26	6.27	N	1	12.8	10.8	31.5	1800
27	6.29	D	1	22.0	22.0	19.2	1050
28	7.03	N	1	42.3	14.1	38.0	1830
29	7.05	D	1	10.7	10.4	.	1315
30	7.07	N	1	27.7	9.9	25.0	2315
31	7.11	D	1	14.8	12.3	26.5	1600
32	7.13	N	1	56.5	8.7	27.8	1810
33	7.17	D	1	10.1	7.8	65.5	1320
34	7.19	N	1	19.8	7.0	13.6	1920
35	7.21	D	1	69.0	47.0	63.6	900
36	7.25	N	1	93.6	53.5	113.2	2000
37	7.27	D	1	167.3	73.6	87.7	1500
38	7.31	N	1	140.9	43.5	70.8	1935
39	8.02	D	1	136.4	45.0	112.7	1100
40	8.08	D	3	81.8	58.5	65.5	1600
41	8.10	N	3	70.0	67.0	82.3	2015
42	8.14	D	1	69.0	36.0	50.5	955
43	8.16	N	1	4090.0	79.1	160.9	2000
44	8.17	D	1	.	90.5	144.6	1500
45	8.18	D	1	.	98.2	150.5	1500
46	8.22	N	1	.	28.6	49.5	1230
47	8.24	D	1	.	110.0	204.1	1230
48	8.30	D	1	.	250.0	190.0	1300
49	8.31	D	1	.	285.5	135.5	1130
50	9.01	N	1	.	71.0	101.4	1915
51	9.05	D	1	9.2	142.3	214.6	800
52	9.07	N	1	9.5	51.5	69.5	2035
53	9.11	D	1	8.5	66.4	175.0	1700
54	9.13	N	1	10.5	9.5	126.4	1930

(continued)

TABLE E-3 (continued)

OBS	DATE	DNCODE	LOCATION	TVIAB	TCOLI	FCOLI	TIME
55	9.14	N	1	10.8	84.5	149.6	1340
56	9.19	N	1	132.3	58.0	64.1	2000
57	9.21	D	1	12.9	82.3	179.1	1100
58	9.25	N	1	39.0	146.8	83.2	2100
59	9.28	D	1	60.5	40.6	97.7	1230
60	9.29	D	1	10.8	13.5	62.7	1815
61	10.04	D	1	49.0	66.5	76.4	1400
62	10.05	N	1	40.0	95.0	75.9	1830
63	10.09	D	1	75.0	118.6	39.5	1630
64	10.11	N	1	32.5	68.0	81.4	1800
65	10.13	D	1	14.0	51.0	37.5	1300
66	10.17	N	1	10.2	22.0	146.4	1800
67	10.19	D	1	40.5	70.0	88.6	1000
68	10.25	D	1	49.0	49.0	79.5	1100
69	10.27	N	1	64.0	77.5	94.1	2100
70	10.31	D	1	24.0	22.5	16.5	1000
71	11.02	N	1	47.0	47.5	250.0	2100
72	11.02	D	1	31.5	30.0	44.4	930
73	11.06	D	1	73.0	40.0	107.2	1045
74	11.08	N	1	64.0	30.5	109.5	1840
75	11.10	D	1	14.2	12.9	50.0	1030
76	11.14	N	1	61.0	79.5	71.8	1800
77	11.16	D	1	70.5	98.2	105.9	1300
78	11.20	N	1	43.0	57.0	67.2	2000
79	11.22	N	1	22.0	47.0	73.6	1645
80	11.24	D	1	5.6	9.3	21.0	1000
81	11.28	N	1	47.5	25.0	25.1	1930
82	11.30	N	1	24.9	31.0	45.5	1930
83	11.30	D	1	4.0	35.0	54.0	1130

TABLE E-4. GAS DATA SET

OBS	DATE	LOCATION	NH3CONC	CL2CONC	H2SCONC	NO2CONC	SO2CONC	NH3LIMIT	CL2LIMIT	H2SLIMIT	NO2LIMIT	SO2LIMIT
1	.		.	.	.	.	.	.	.	.	.	.
2	5.19	A	.	.	.	12.1	.	.	.	0.0	.	31.5
3	5.19	B	.	.	.	14.1	.	.	.	0.0	.	31.5
4	5.24	A	.	.	.	78.8	.	.	.	0.7	.	28.8
5	5.24	C	.	.	.	117.9	.	.	.	0.7	.	31.0
6	5.24	D	.	.	.	108.6	.	.	.	0.9	.	41.0
7	5.29	A	.	.	.	25.3	.	.	.	0.7	.	34.9
8	5.29	B	.	.	.	24.1	.	.	.	0.7	.	31.5
9	5.29	E	.	.	.	24.1	.	.	.	0.7	.	31.5
10	6.03	A	.	.	4.3	61.3	.	.	.	.	.	31.5
11	6.03	D	.	.	4.4	45.9	.	.	.	.	.	31.5
12	6.05	C	.	.	3.7	48.8	.	.	.	.	.	34.9
13	6.08	A	.	.	.	60.7	.	.	.	0.7	.	33.8
14	6.08	B	.	.	.	64.7	.	.	.	0.7	.	31.0
15	6.08	E	.	.	.	59.2	.	.	.	0.7	.	28.8
16	6.13	A	.	.	.	25.1	.	.	.	0.7	.	33.8
17	6.13	C	.	.	.	26.3	.	.	.	0.7	.	28.8
18	6.13	D	.	.	.	38.7	.	.	.	0.7	.	31.0
19	6.18	A	.	18.5	.	38.0	.	.	.	0.7	.	3.5
20	6.18	B	.	20.3	.	48.4	7.2	.	.	0.7	.	.
21	6.18	E	.	12.8	.	47.2	6.4	.	.	0.7	.	.
22	6.23	A	.	7.3	.	.	.	.	.	0.7	.	.
23	6.23	C	.	11.3	.	73.4	25.4	.	.	0.7	.	.
24	6.23	D	.	23.1	.	55.1	24.4	.	.	0.7	.	.
25	6.28	A	.	5.7	.	.	.	.	.	0.7	.	3.0
26	6.28	B	.	10.4	.	66.8	11.0	.	.	0.7	.	.
27	6.28	E	.	7.0	.	.	.	.	.	0.7	6.1	.
28	7.03	A	.	25.6	.	32.6	14.1	.	.	0.8	.	.
29	7.03	C	.	8.6	.	51.4	17.5	.	.	0.7	.	.
30	7.03	D	.	5.2	.	9.5	5.4	.	.	0.7	.	.
31	7.08	A	.	10.5	.	31.7	11.0	.	.	0.7	.	.
32	7.08	B	.	8.7	.	.	3.6	.	.	0.6	5.0	.
33	7.08	E	.	.	.	43.9	11.0	.	.	0.7	.	.
34	7.13	A	.	22.4	.	45.0	9.5	.	.	0.7	.	.
35	7.13	C	.	14.5	.	55.6	13.2	.	.	0.7	.	.
36	7.13	D	.	19.2	.	44.8	11.1	.	.	0.6	.	.
37	7.17	A	.	5.6	.	34.4	10.3	.	.	0.7	.	.
38	7.18	B	.	14.7	.	20.9	8.7	.	.	0.7	.	.
39	7.18	E	.	19.1	.	77.1	10.6	.	.	0.7	.	.
40	7.23	A	.	9.8	.	72.4	14.4	.	.	0.6	.	.
41	7.23	C	.	12.7	.	85.9	17.6	.	.	0.7	.	.
42	7.28	A	.	23.9	.	219.9	15.6	.	.	0.7	.	.
43	7.28	B	.	20.0	.	163.9	9.2	.	.	0.7	.	.
44	7.28	E	.	23.0	.	135.5	8.0	.	.	0.6	.	.
45	8.02	A	.	7.6	.	66.3	3.6	.	.	0.6	.	.
46	8.02	C	.	13.1	.	80.1	17.2	.	.	0.7	.	.
47	8.02	D	.	12.7	.	70.1	19.4	.	.	0.7	.	.
48	8.07	A	.	13.1	.	46.4	1.7	.	.	0.7	.	.
49	8.07	B	.	12.8	.	49.2	1.6	.	.	0.7	.	.
50	8.12	A	.	12.3	.	3.6	5.1	.	.	0.7	.	.
51	8.12	D	.	26.0	.	76.1	5.0	.	.	0.7	.	.
52	8.17	A	.	10.4	.	51.3	.	.	.	0.8	.	.
53	8.17	E	.	12.6	.	46.4	.	.	.	0.8	.	3.1
54	8.22	A	.	15.6	.	.	.	.	.	0.8	.	3.2

(continued)

TABLE E-4 (continued)

OBS	DATE	LOCATION	NH3CONC	CL2CONC	H2SCONC	NO2CONC	SO2CONC	NH3LIMIT	CL2LIMIT	H2SLIMIT	NO2LIMIT	SO2LIMIT
55	8.22	C	.	12.0	.	78.0	.	.	.	0.8	.	3.1
56	8.27	A	.	22.8	.	30.9	2.0	.	.	0.9	.	.
57	8.27	B	.	20.0	.	68.9	11.9	.	.	0.7	.	.
58	8.27	E	.	17.2	.	41.5	4.7	.	.	0.8	.	.
59	9.01	A	.	2.7	.	52.1	.	.	.	0.8	.	3.0
60	9.01	C	.	13.6	.	40.5	4.3	.	.	0.9	.	.
61	9.01	D	.	8.6	.	82.3	3.6	.	.	0.7	.	.
62	9.06	A	.	20.3	.	165.9	.	.	.	0.8	.	3.3
63	9.06	B	.	14.5	.	127.3	4.7	.	.	0.9	.	.
64	9.06	E	.	.	.	219.2	3.8	.	1.7	0.7	.	.
65	9.11	A	.	6.8	.	51.7	.	2.8	.	0.8	.	3.3
66	9.11	C	.	17.0	.	131.7	.	2.6	.	0.7	.	3.2
67	9.11	D	.	15.2	.	144.0	6.0	2.6	.	0.7	.	.
68	9.16	A	.	7.9	.	25.5	.	.	.	0.7	.	3.2
69	9.16	D	.	.	.	.	.	.	1.1	0.8	.	3.0
70	9.16	E	.	.	.	23.0	.	.	.	0.9	.	.
71	9.21	A	.	12.1	.	21.7	.	2.6	.	0.9	.	3.0
72	9.21	C	.	12.4	.	.	13.1	2.7	.	0.7	.	.
73	9.21	D	.	10.6	.	18.4	10.3	2.8	.	0.9	.	.
74	9.26	A	.	.	.	28.7	.	2.6	.	.	.	3.0
75	9.26	B	.	.	.	.	.	2.8	.	.	.	.
76	9.26	E	.	14.5	.	25.2	.	2.8	.	0.8	.	3.3
77	10.01	A	.	11.5	.	23.3	.	2.2	.	.	.	3.3
78	10.01	C	.	23.0	.	26.8	.	2.2	.	.	.	3.6
79	10.01	D	.	16.7	.	22.5	.	2.3	.	.	.	3.3
80	10.06	A	.	19.0	.	17.7	.	2.3	.	.	.	3.4
81	10.06	E	.	36.9	.	22.9	5.5	2.2	.	.	.	.
82	10.11	A	.	22.5	.	11.6	.	2.2	.	.	.	3.4
83	10.11	C	.	12.7	.	14.0	.	2.3	.	.	.	3.4
84	10.16	A	.	12.5	.	31.0	8.5	2.2	.	.	.	.
85	10.16	B	.	13.4	.	30.6	8.0	2.1	.	.	.	.
86	10.16	E	.	16.1	.	40.0	.	2.3	.	.	.	3.0
87	10.21	A	2.9	8.4	.	29.0	.	.	.	.	.	3.5
88	10.21	C	.	15.4	.	33.7	3.5	2.1	.	.	.	.
89	10.21	D	2.3	19.3	.	15.7	50.9	.	.	.	.	.
90	10.26	A	.	11.2	.	32.9	.	2.2	.	.	.	3.4
91	10.26	B	.	13.5	.	34.4	.	.	.	.	.	3.3
92	10.26	E	.	11.0	.	31.2	.	2.1	.	.	.	3.5
93	10.31	A	.	12.1	.	37.9	22.5	2.2	.	.	.	.
94	10.31	C	.	7.7	.	32.0	.	2.3	.	.	.	4.2
95	10.31	D	.	3.7	.	39.4	4.1	2.2	.	.	.	.
96	11.05	A	5.2	13.8	.	11.5	.	.	.	.	.	3.3
97	11.05	B	3.3	15.4	.	19.3	.	.	.	.	.	3.4
98	11.05	E	4.5	7.7	.	36.5	.	.	.	.	.	4.2
99	11.10	A	5.6	8.8	.	54.6	.	.	.	.	.	4.1
100	11.10	D	4.0	29.5	.	30.1	.	.	.	.	.	2.9
101	11.15	A	.	19.3	.	24.5	.	.	.	.	.	2.9
102	11.15	B	.	19.9	.	23.7	53.8	2.1	.	.	.	.
103	11.15	E	.	16.3	.	17.3	.	2.4	.	.	.	3.4
104	11.20	A	.	18.0	.	57.3	.	2.3	.	.	.	3.3
105	11.20	C	2.9	17.3	.	70.5	8.6	.	.	.	.	.
106	11.20	D	2.9	25.7	.	73.4	.	.	.	.	.	2.9
107	11.25	B	4.5	19.8	.	90.5	.	.	.	.	.	4.1
108	11.25	E	.	11.3	.	72.6	.	2.3	.	.	.	3.3

TABLE E-5. PARTICULATE DATA SET

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
1	4.04	B	M	G	47.1	1.44	11.12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	4.04	F	M	G	49.0	1.32	11.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	4.09	B	M	G	104.0	1.87	10.42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	4.14	B	M	G	70.9	2.03	10.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	4.14	F	M	G	94.0	1.67	8.99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	4.19	B	M	G	104.0	1.97	10.51	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	4.19	F	M	G	120.8	2.35	17.62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	4.24	F	M	G	40.1	0.72	6.37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9	4.29	B	M	G	76.7	1.68	9.28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	4.29	F	M	G	91.6	1.89	11.92	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
11	5.09	B	M	G	25.2	0.30	6.47	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12	5.14	B	M	G	146.0	2.58	12.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13	5.15	A	2	G	52.7	1.21	13.22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14	5.19	A	1	G	111.1	2.25	15.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
15	5.19	A	2	G	113.6	2.23	15.71	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	5.19	B	M	G	135.0	2.20	16.45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17	5.24	A	1	G	142.4	2.58	22.69	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18	5.24	A	2	G	148.8	2.98	23.79	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
19	5.24	B	M	G	164.1	2.04	22.26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
20	5.24	C	M	G	143.4	2.74	21.74	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21	5.24	D	M	G	137.5	2.18	27.39	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
22	5.29	A	1	G	111.3	2.18	22.78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
23	5.29	A	2	G	104.5	1.50	21.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
24	5.29	B	M	G	35.6	1.21	19.56	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
25	5.29	C	M	G	134.9	1.35	21.42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
26	5.29	D	M	G	126.1	1.69	21.45	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
27	5.29	E	M	G	149.1	1.70	21.51	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28	6.03	A	2	G	53.1	0.63	6.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
29	6.03	A	1	G	55.6	0.93	5.55	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
30	6.03	B	M	G	63.7	0.78	5.16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
31	6.03	D	M	G	65.7	0.93	5.80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
32	6.03	E	M	G	59.6	0.43	5.42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
33	6.05	C	M	G	97.6	2.41	21.12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
34	6.08	A	2	G	50.1	1.07	9.13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
35	6.08	A	1	G	69.3	1.73	9.30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
36	6.08	B	M	G	135.6	1.62	8.46	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
37	6.08	C	M	G	67.6	1.80	8.42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
38	6.08	D	M	G	54.1	1.75	9.12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
39	6.08	E	M	G	62.3	1.55	7.62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
40	6.13	A	2	G	48.6	1.32	11.80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
41	6.13	A	1	G	47.8	1.32	13.67	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
42	6.13	B	M	G	83.5	0.73	12.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
43	6.13	C	M	G	51.2	0.86	13.51	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44	6.13	D	M	G	52.7	0.80	13.27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
45	6.13	E	M	G	93.8	1.11	12.72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46	6.18	A	2	G	44.6	1.13	8.08	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
47	6.18	A	1	G	44.8	1.23	8.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

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TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
48	6.18	B	H	G	41.6	0.73	6.97	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49	6.18	C	H	G	64.8	1.12	7.56	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
50	6.18	D	H	G	56.8	1.10	7.93	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
51	6.18	E	H	G	42.1	0.77	7.10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
52	6.23	A	2	G	120.6	2.87	24.28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
53	6.23	A	1	G	123.0	0.22	24.03	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
54	6.23	B	H	G	108.4	1.00	19.22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
55	6.23	C	H	G	152.2	2.65	23.40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
56	6.23	D	H	G	146.5	2.76	23.79	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
57	6.23	E	H	G	100.9	1.57	20.14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
58	6.28	A	2	G	82.8	1.47	15.57	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
59	6.28	A	1	.	62.9	.	.	.	0.005	9	.	.	0.031	9	.	.	0.139	9	.	9	.	9	.	9
60	6.28	B	H	B	34.6	.	.	9	.	9	.	9	.	9	.	.	0.403	9	.	9	.	9	.	9
61	6.28	C	H	G	126.1	1.43	15.92	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
62	6.28	D	H	G	92.3	1.20	15.38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
63	6.28	E	H	A	35.0	.	.	9	.	9	.	.	0.025	9	.	.	0.213	9	.	9	.	9	.	9
64	7.03	A	1	G	91.9	1.68	17.24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
65	7.03	A	2	B	80.6	.	.	.	0.003	9	.	.	0.048	9	.	.	0.066	9	.	9	.	9	.	9

OBS	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
48	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
49	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
51	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
52	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
53	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
54	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
55	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
56	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
57	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
58	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
59	.	9	.	9	.	.	0.435	.	0.039	.	0.016	.	0.011	0.008	0.013	0.011	0.011	0.021	.
60	.	9	.	9	.	.	0.785	0.002	0.036	0.026	0.014	.	0.010	0.007	0.012	0.010	0.010	0.019	.
61	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
63	.	9	.	9	.	.	0.559	0.002	0.034	.	0.014	.	0.009	0.007	0.012	0.009	0.009	0.018	.
64	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
65	.	9	.	9	.	.	0.277	.	0.038	.	0.015	.	0.010	0.008	0.013	0.010	0.010	0.020	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
66	7.03	C	H	■	81.5	.	.	.	0.002	9	.	.	0.041	9	.	.	0.171	9	.	9	.	9	.	9
67	7.03	D	H	■	93.4	.	.	.	0.004	9	.	.	0.024	9	.	.	0.120	9	.	9	.	9	.	9
68	7.03	E	H	G	97.0	2.68	25.39	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
69	7.08	A	2	G	85.8	1.45	12.87	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
70	7.08	A	1	■	57.7	.	.	.	0.006	9	.	.	0.064	9	.	.	0.245	9	.	.	0.022	9	.	9
71	7.08	B	H	■	36.3	.	.	9	.	9	.	9	.	9	.	.	0.469	9	.	9	.	9	.	9
72	7.08	C	H	G	149.6	1.82	14.29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
73	7.08	D	H	G	115.1	1.95	13.82	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
74	7.08	E	H	■	45.9	.	.	.	0.007	9	.	.	0.060	9	.	.	0.258	9	.	.	0.010	9	.	9
75	7.13	A	1	G	60.2	1.23	8.14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
76	7.13	A	2	■	26.5	.	.	9	.	9	.	.	0.035	9	.	.	0.113	9	.	9	.	9	.	9
77	7.13	B	H	G	60.8	1.29	7.89	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
78	7.13	C	H	■	64.0	.	.	9	.	.	0.052	.	0.054	9	.	.	0.326	9	.	9	.	9	.	9
79	7.13	D	H	■	35.5	.	.	.	0.002	9	.	.	0.023	9	.	.	0.343	9	.	9	.	9	.	9
80	7.13	E	H	G	56.3	1.39	7.88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
81	7.18	A	2	G	86.8	1.36	6.40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
82	7.18	A	1	■	46.6	.	.	.	0.004	9	.	.	0.031	9	.	.	0.261	9	.	9	.	9	.	9
83	7.18	C	H	G	52.2	1.40	9.54	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
66	.	9	.	9	.	.	0.422	.	0.034	.	0.014	.	0.009	0.007	0.011	0.009	0.009	0.018	.
67	.	9	.	9	.	.	0.321	.	0.030	.	0.012	.	0.008	0.006	0.010	0.008	0.008	0.016	.
68	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
69	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
70	.	9	.	9	.	.	1.305	.	0.042	.	0.017	.	0.011	.	0.014	0.011	0.011	0.022	.
71	.	9	.	9	.	.	0.128	0.002	0.031	0.023	0.012	.	0.008	0.006	0.011	0.008	0.008	0.017	.
72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
73	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
74	.	9	.	9	.	.	1.567	.	0.036	.	0.014	.	0.010	.	0.012	0.010	0.010	0.019	.
75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
76	.	9	.	9	.	.	0.393	0.002	0.038	.	0.015	.	0.010	0.007	0.012	0.010	0.010	0.020	.
77	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
78	.	9	.	9	.	.	0.553	0.002	.	.	0.015	.	0.010	0.007	0.012	0.010	0.010	0.020	.
79	.	9	.	9	.	.	0.521	.	0.031	.	0.013	.	0.008	0.006	0.011	0.008	0.008	0.017	.
80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
81	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
82	.	9	.	9	.	.	0.276	.	0.033	.	0.013	.	0.009	0.007	0.011	0.009	0.009	0.018	.
83	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
84	7.18	D	M	G	55.9	1.45	8.17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
85	7.18	E	M	W	64.3	.	.	.	0.004	9	.	.	0.024	9	.	.	0.289	9	.	9	.	9	.	9	.
86	7.23	A	1	G	79.4	2.01	12.60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
87	7.23	A	2	W	82.3	.	.	.	0.009	9	.	9	.	9	.	.	0.210	9	.	9	.	9	.	.	0.012
88	7.23	B	M	G	69.9	1.40	13.64	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
89	7.23	C	M	W	74.6	.	.	.	0.004	9	.	9	.	9	.	.	0.252	9	.	9	.	9	.	9	.
90	7.23	D	M	W	71.3	.	.	9	.	9	.	9	.	9	.	.	0.449	9	.	9	.	9	.	9	.
91	7.23	E	M	G	74.9	1.36	13.34	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
92	7.28	A	2	G	93.5	1.76	20.44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
93	7.28	A	1	W	77.6	.	.	.	0.005	9	.	9	.	9	.	.	0.076	9	.	9	.	9	.	9	.
94	7.28	B	M	W	63.9	.	.	.	0.004	9	.	9	.	9	.	.	0.109	9	.	9	.	9	.	9	.
95	7.28	C	M	G	138.9	1.60	19.09	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
96	7.28	D	M	G	153.1	1.21	16.57	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
97	7.28	E	M	W	76.6	.	.	.	0.005	9	.	9	.	9	.	.	0.181	9	.	.	0.014	.	0.016	.	0.009
98	8.02	A	1	G	65.2	1.13	10.31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
99	8.02	A	2	W	74.5	.	.	.	0.005	9	.	9	.	9	.	.	0.155	9	.	.	0.008	.	0.018	9	.
100	8.02	B	M	G	61.4	1.10	8.93	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
101	8.02	C	M	W	94.0	.	.	.	0.004	9	.	9	.	9	.	.	0.259	9	.	9	.	.	0.013	9	.

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
84	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
85	9	.	9	.	.	0.703	.	0.033	.	0.013	.	0.009	0.007	0.011	0.009	0.009	0.016	.
86	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
87	9	.	9	.	.	1.001	.	0.045	0.033	0.018	.	0.012	0.009	0.015	.	0.012	0.024	.
88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
89	9	.	9	.	.	1.280	.	0.031	0.023	0.012	.	0.008	0.006	0.010	0.008	0.008	0.017	.
90	.	0.018	9	.	.	0.842	0.002	0.031	0.022	0.012	.	0.008	0.006	0.010	0.006	.	0.016	.
91	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
92	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
93	.	0.012	9	.	.	0.589	.	0.038	0.028	0.015	.	0.010	0.007	0.013	0.010	.	0.020	.
94	.	0.026	9	.	.	0.755	.	0.030	0.022	0.012	.	0.008	0.006	0.010	0.008	.	0.016	.
95	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
96	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
97	.	0.021	9	.	.	0.960	.	0.035	0.025	0.014	.	0.009	.	.	.	.	0.019	.
98	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
99	9	.	9	.	.	0.605	.	0.039	0.029	0.016	.	0.011	.	.	0.011	0.011	0.021	.
100	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
101	9	.	9	.	.	0.863	.	0.031	0.023	0.013	.	0.008	0.006	.	0.008	0.008	0.017	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
102	8.02	D	M	*	89.1	.	.	.	0.004	9	.	9	.	9	.	.	0.410	9	.	9	.	9	.	9	.
103	8.02	E	M	G	62.5	1.02	9.48	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
104	8.07	A	2	G	53.4	2.40	20.52	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
105	8.07	A	1	*	11.8	.	.	.	0.032	9	.	.	0.030	9	.	.	0.119	9	.	.	0.016	.	0.023	.	0.012
106	8.07	B	M	*	1.1	.	.	.	0.002	9	.	9	.	9	.	.	0.112	9	.	9	.	9	.	.	0.016
107	8.07	D	M	G	55.0	1.37	11.79	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
108	8.07	E	M	*	13.0	.	.	.	0.032	9	.	9	.	9	.	.	0.317	9	.	9	.	.	0.047	.	0.013
109	8.12	A	1	G	64.6	1.45	7.18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
110	8.12	A	2	*	47.7	.	.	.	0.002	9	.	.	0.057	9	.	.	0.122	9	.	9	.	9	.	.	0.012
111	8.12	B	M	G	61.7	0.60	6.81	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
112	8.12	D	M	*	58.3	.	.	.	0.002	9	.	.	0.044	9	.	.	0.514	9	.	.	0.013	9	.	9	.
113	8.12	E	M	G	56.1	1.24	5.78	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
114	8.17	A	2	G	37.8	1.78	6.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
115	8.17	A	1	*	7.1	.	.	9	.	9	.	9	.	9	.	.	0.145	9	.	9	.	.	0.017	9	.
116	8.17	C	M	G	69.7	0.46	7.02	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
117	8.17	D	M	G	53.1	0.59	6.06	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
118	8.17	E	M	*	17.6	.	.	9	.	9	.	.	0.029	9	.	.	0.266	9	.	9	.	9	.	9	.
119	8.22	A	M	*	215.6	.	.	.	0.002	9	.	.	0.027	9	.	.	0.279	9	.	9	.	9	.	.	0.009

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
102	9	.	9	.	.	0.676	.	0.032	0.024	0.013	.	0.009	0.006	0.011	0.009	0.009	0.017	.
103	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
104	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
105	.	0.012	9	.	.	0.928	.	0.023	.	0.009	.	0.012	.	.	.	.	0.009	.
106	9	.	9	.	.	1.269	.	0.021	0.021	0.008	.	0.010	0.006	0.008	.	0.008	0.008	.
107	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
108	.	0.017	9	.	.	0.870	.	0.022	0.022	0.008	.	0.011	0.006	.	.	.	0.008	.
109	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
110	.	0.012	9	.	.	1.120	.	0.025	.	0.010	.	0.012	0.007	0.010	.	.	0.010	.
111	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
112	9	.	9	.	.	1.171	.	0.022	.	0.009	.	0.011	.	0.009	0.009	0.009	0.009	.
113	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
114	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
115	9	.	9	.	.	0.316	0.002	0.024	0.024	0.010	.	0.012	0.007	.	0.010	0.010	0.010	.
116	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
117	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
118	9	.	9	.	.	0.631	0.002	0.022	.	0.009	.	0.011	0.007	0.009	0.009	0.009	0.009	.
119	9	.	9	.	.	0.588	.	0.022	.	0.009	.	0.011	0.007	0.009	.	0.009	0.009	.

(continued)

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TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
120	8.22	A	H	1	16.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
121	8.22	A	H	2	20.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
122	8.22	A	H	3	13.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
123	8.22	A	H	4	8.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
124	8.22	A	H	5	11.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
125	8.22	B	H	G	52.4	0.90	5.83	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
126	8.22	C	H	*	51.8	.	.	.	0.002	9	.	.	0.048	9	.	.	0.466	9	.	9	.	9	.	9	.
127	8.22	D	H	*	35.3	.	.	.	0.002	9	.	.	0.030	9	.	.	0.433	9	.	.	0.006	.	0.013	9	.
128	8.22	E	H	G	53.8	0.88	6.41	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
129	8.27	A	H	*	94.8	.	.	.	0.004	9	.	.	0.040	9	.	.	0.035	9	.	9	.	9	.	9	.
130	8.27	A	H	1	29.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
131	8.27	A	H	2	21.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
132	8.27	A	H	3	10.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
133	8.27	A	H	4	15.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
134	8.27	A	H	5	33.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
135	8.27	B	H	*	98.4	.	.	.	0.007	9	.	.	0.018	9	.	.	0.081	9	.	9	.	9	.	9	.
136	8.27	C	H	G	91.6	0.73	20.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
137	8.27	D	H	G	81.3	0.80	16.52	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
120	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
121	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
122	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
123	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
124	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
125	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
126	9	.	9	.	.	1.224	.	0.023	.	0.009	.	0.011	0.007	0.009	0.009	0.009	0.009	.
127	9	.	9	.	.	0.621	.	0.021	.	0.008	.	0.011	.	.	0.008	0.008	0.008	.
128	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
129	.	0.009	9	.	.	0.271	.	0.022	.	0.009	.	0.011	0.007	0.009	0.009	.	0.009	.
130	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
131	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
132	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
133	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
134	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
135	9	.	9	.	.	0.308	.	0.018	.	0.007	.	0.009	0.005	0.007	0.007	0.007	0.007	.
136	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
137	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
138	8.27	E	H	*	85.8	.	.	.	0.004	9	.	.	0.038	9	.	.	0.220	9	.	9	.	.	0.012	9	.
139	9.01	A	H	*	10.6	.	.	.	0.002	9	.	9	.	9	.	.	0.138	9	.	9	.	9	.	9	.
140	9.01	A	H	1	7.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
141	9.01	A	H	2	7.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
142	9.01	A	H	3	5.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
143	9.01	A	H	4	7.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
144	9.01	A	H	5	5.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
145	9.01	B	H	G	14.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
146	9.01	C	H	*	15.3	.	.	.	0.004	9	.	.	0.043	9	.	.	0.870	9	.	9	.	9	.	.	0.014
147	9.01	D	H	*	21.2	.	.	.	0.002	9	.	.	0.032	9	.	.	0.452	9	.	9	.	.	0.013	.	0.011
148	9.01	E	H	G	33.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
149	9.06	A	H	*	7.9	.	.	.	0.004	9	.	9	.	9	.	.	0.317	9	.	9	.	9	.	9	.
150	9.06	A	H	1	7.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
151	9.06	A	H	2	3.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
152	9.06	A	H	3	0.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
153	9.06	A	H	4	12.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
154	9.06	A	H	5	4.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
155	9.06	B	H	*	99.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
138	9	.	9	.	.	0.337	.	0.021	.	0.008	.	0.010	0.006	.	0.008	0.008	0.008	.
139	9	.	9	.	.	0.491	.	0.023	0.023	0.009	.	0.011	0.007	0.009	0.009	0.009	0.009	.
140	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
141	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
142	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
143	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
144	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
145	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
146	9	.	9	.	.	1.031	.	0.023	.	0.009	.	0.011	0.007	0.009	.	0.009	0.009	.
147	.	0.011	9	.	.	0.664	.	0.021	.	0.008	.	0.011	0.006	.	.	.	0.008	.
148	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
149	9	.	9	.	.	0.564	.	0.023	0.023	0.009	.	0.011	0.007	0.009	0.009	0.009	0.009	.
150	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
151	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
152	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
153	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
154	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
155	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
156	9.06	C	H	G	61.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
157	9.06	D	H	G	56.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
158	9.06	E	H	W	5.5	.	.	9	.	9	.	9	.	9	.	.	0.326	9	.	.	0.007	9	.	9	.
159	9.11	A	H	W	52.4	.	.	.	0.002	9	.	.	0.050	9	.	.	0.375	9	.	9	.	9	.	.	0.012
160	9.11	A	H	1	75.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
161	9.11	A	H	2	78.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
162	9.11	A	H	3	67.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
163	9.11	A	H	4	67.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
164	9.11	A	H	5	10.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
165	9.11	B	H	G	72.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
166	9.11	C	H	W	82.4	.	.	.	0.002	9	.	.	0.078	9	.	.	0.991	9	.	.	0.019	.	0.014	9	.
167	9.11	D	H	W	66.1	.	.	.	0.004	9	.	.	0.046	9	.	.	0.399	9	.	.	0.007	9	.	9	.
168	9.11	E	H	G	62.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
169	9.16	A	H	W	56.8	.	.	.	0.005	9	.	.	0.056	9	.	.	0.266	9	.	.	0.013	.	0.015	.	0.015
170	9.16	A	H	1	22.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
171	9.16	A	H	2	14.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
172	9.16	A	H	3	7.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
173	9.16	A	H	4	8.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
156	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
157	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
158	9	.	9	.	.	0.952	0.002	0.023	0.023	0.009	.	0.011	.	0.009	0.009	0.009	0.009	.
159	9	.	9	.	.	1.092	.	0.025	.	0.010	.	0.012	0.007	0.010	.	0.010	0.010	.
160	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
161	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
162	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
163	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
164	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
165	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
166	9	.	9	.	.	1.930	.	0.024	.	0.009	.	0.012	.	.	0.009	0.009	0.009	.
167	9	.	9	.	.	1.116	.	0.022	.	0.009	.	0.011	.	0.009	0.009	0.009	0.009	.
168	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
169	.	0.013	.	0.013	.	1.446	.	0.025	.	0.010	.	0.013	.	.	.	.	.	.
170	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
171	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
172	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
173	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
174	9.16	A	M	S	21.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
175	9.16	B	M	W	62.2	.	.	.	0.005	9	.	.	0.077	9	.	.	0.458	9	.	.	0.016	9	.	.	0.011
176	9.16	C	F	G	67.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
177	9.16	D	F	G	78.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
178	9.16	E	M	W	46.6	.	.	.	0.004	9	.	.	0.064	9	.	.	0.262	9	.	.	0.015	.	0.019	.	0.011
179	9.21	A	F	W	54.9	.	.	9	.	9	.	.	0.034	9	.	.	0.367	9	.	9	.	9	.	9	.
180	9.21	A	M	1	12.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
181	9.21	A	M	2	8.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
182	9.21	A	M	3	2.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
183	9.21	A	F	4	4.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
184	9.21	A	F	5	9.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
185	9.21	B	M	G	37.9	0.50	8.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
186	9.21	C	F	W	74.2	.	.	9	.	9	.	.	0.024	9	.	.	0.394	9	.	9	.	9	.	9	.
187	9.21	D	M	W	55.2	.	.	9	.	9	.	9	.	9	.	.	0.623	9	.	9	.	9	.	9	.
188	9.21	E	M	G	61.2	0.70	10.52	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
189	9.26	A	F	W	45.2	.	.	9	.	9	.	.	0.063	9	.	.	0.257	9	.	.	0.013	9	.	9	.
190	9.26	B	F	W	45.8	.	.	9	.	9	.	.	0.083	9	.	.	0.566	9	.	.	0.013	9	.	9	.
191	9.26	C	M	G	83.1	0.72	8.88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
174	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
175	.	0.016	9	.	.	1.080	.	0.023	.	0.009	.	0.011	.	0.009	.	.	0.009	.
176	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
177	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
178	9	.	9	.	.	1.200	.	0.021	.	0.008	.	0.011	.	.	.	0.008	0.008	.
179	9	.	9	.	.	0.391	0.002	0.024	.	0.010	.	0.012	0.007	0.010	0.010	0.010	0.010	.
180	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
181	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
182	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
183	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
184	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
185	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
186	9	.	9	.	.	0.543	0.002	0.022	.	0.009	.	0.011	0.006	0.009	0.009	0.009	0.009	.
187	9	.	9	.	.	0.393	0.002	0.022	0.022	0.009	.	0.011	0.007	0.009	0.009	0.009	0.009	.
188	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
189	9	.	9	.	.	0.662	0.002	0.022	.	0.009	.	0.011	.	0.009	0.009	0.009	0.009	.
190	9	.	9	.	.	0.787	0.002	0.022	.	0.009	.	0.011	.	0.009	0.009	0.009	0.009	.
191	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
192	9.26	D	H	G	57.7	0.01	6.77	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
193	9.26	E	H	W	37.1	.	.	9	.	9	.	.	0.035	9	.	.	0.304	9	.	9	.	.	0.016	9
194	10.01	A	H	*	13.0	.	.	9	.	9	.	9	.	9	.	.	0.099	9	.	9	.	9	.	9
195	10.01	A	H	1	2.6	0.02	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
196	10.01	A	H	2	2.9	0.31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
197	10.01	A	H	3	0.6	0.12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
198	10.01	A	H	4	0.3	0.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
199	10.01	A	H	5	2.2	0.30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
200	10.01	B	H	G	21.3	0.01	6.77	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
201	10.01	C	H	*	13.6	.	.	.	0.002	9	.	9	.	9	.	.	0.211	9	.	9	.	9	.	9
202	10.01	D	H	W	13.5	.	.	9	.	9	.	9	.	9	.	.	0.352	9	.	9	.	9	.	9
203	10.01	E	H	G	23.0	0.56	9.62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
204	10.06	A	H	*	.	.	.	9	.	9	.	9	.	9	.	.	0.373	9	.	9	.	9	.	9
205	10.06	A	H	1	.	0.08	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
206	10.06	A	H	2	.	0.08	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
207	10.06	A	H	3	.	0.07	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
208	10.06	A	H	4	.	0.06	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
209	10.06	A	H	5	.	0.28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
192	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
193	.	9	.	9	.	.	0.041	0.002	0.023	.	0.009	.	0.011	0.007	.	0.009	0.009	0.009	.
194	.	9	.	9	.	.	0.106	0.002	0.022	0.022	0.009	.	0.011	0.007	0.009	0.009	0.009	0.009	.
195	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
196	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
197	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
198	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
199	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
200	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
201	.	9	.	9	.	.	0.155	.	0.020	0.020	0.008	.	0.010	0.006	0.008	0.008	0.008	0.008	.
202	.	9	.	9	.	.	0.286	0.004	0.025	0.023	0.008	.	0.006	0.006	0.015	0.010	0.010	0.008	.
203	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
204	.	9	.	9	.	.	0.436	0.005	0.030	0.028	0.010	.	0.008	0.008	0.018	0.013	0.013	0.010	.
205	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
206	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
207	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
208	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
209	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CHCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
210	10.06	B	H	.	13.3	.	.	9	.	9	.	9	.	9	.	1	0.361	9	.	9	.	9	.	9
211	10.06	C	H	G	61.6	0.58	7.43	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
212	10.06	D	H	G	43.6	0.83	7.54	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
213	10.06	E	H	.	12.5	.	.	9	.	9	.	.	0.055	9	.	.	0.360	9	.	.	0.007	9	.	9
214	10.11	A	H	.	22.8	.	.	9	.	9	.	9	.	9	.	.	0.101	9	.	9	.	.	0.020	9
215	10.11	A	H	1	15.1	0.12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
216	10.11	A	H	2	5.4	0.06	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
217	10.11	A	H	3	2.9	0.16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
218	10.11	A	H	4	1.1	0.06	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
219	10.11	A	H	5	13.3	0.26	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
220	10.11	B	H	G	32.5	0.55	7.86	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
221	10.11	C	H	.	35.9	.	.	9	.	9	.	9	.	9	.	.	0.297	9	.	.	0.007	9	.	9
222	10.11	D	H	.	17.4	.	.	9	.	9	.	.	0.026	9	.	.	0.220	9	.	9	.	9	.	9
223	10.11	E	H	G	33.5	0.53	9.22	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
224	10.16	A	H	.	25.4	.	.	9	.	9	.	9	.	9	.	.	0.425	9	.	9	.	9	.	9
225	10.16	B	H	.	20.4	.	.	9	.	9	.	9	.	9	.	.	0.644	9	.	9	.	9	.	9
226	10.16	C	H	G	35.3	0.34	5.02	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
227	10.16	D	H	G	37.7	0.49	5.94	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SNCONC	SECODE	SBCONC	FGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
210	.	9	.	9	.	.	0.581	0.004	0.027	0.025	0.009	.	0.007	0.007	0.016	0.011	0.011	0.009	.
211	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
212	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
213	.	9	.	9	.	.	0.696	0.005	0.028	.	0.009	.	0.007	.	0.016	0.011	0.011	0.009	.
214	.	9	.	9	.	.	0.329	0.005	0.030	0.027	0.010	.	0.007	0.007	.	0.012	0.012	0.010	.
215	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
216	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
217	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
218	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
219	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
220	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
221	.	9	.	9	.	.	0.925	0.005	0.030	0.027	0.010	.	0.007	.	0.017	0.012	0.012	0.010	.
222	.	9	.	9	.	.	0.253	0.004	0.026	.	0.009	.	0.007	0.007	0.015	0.011	0.011	0.009	.
223	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
224	.	9	.	.	0.009	.	0.475	0.005	0.029	0.026	0.009	.	0.007	0.007	0.017	0.012	0.012	.	.
225	.	9	.	9	.	.	0.877	0.004	0.027	0.025	0.009	.	0.007	0.007	0.016	0.011	0.011	0.009	.
226	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
227	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

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TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
228	10.16	E	H	W	29.5	.	.	9	.	9	.	9	.	9	.	.	0.304	9	.	9	.	9	.	9
229	10.21	A	H	W	110.0	.	.	9	.	9	.	.	0.042	9	.	.	0.117	.	0.014	9	.	.	0.019	9
230	10.21	A	H	1	43.4	0.60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
231	10.21	A	H	2	20.5	0.29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
232	10.21	A	H	3	9.8	0.14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
233	10.21	A	H	4	10.0	0.13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
234	10.21	A	H	5	34.0	0.13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
235	10.21	B	H	G	125.8	0.68	8.70	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
236	10.21	C	H	W	123.2	.	.	9	.	9	.	.	0.063	9	.	.	0.240	9	.	9	.	9	.	9
237	10.21	D	H	W	120.5	.	.	9	.	9	.	.	0.073	9	.	.	0.232	.	0.010	.	0.007	.	0.027	9
238	10.21	E	H	G	128.8	2.39	16.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
239	10.26	A	H	W	67.2	.	.	9	.	9	.	.	0.034	9	.	.	0.395	9	.	.	0.010	9	.	.
240	10.26	A	H	1	19.4	0.44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
241	10.26	A	H	2	9.9	0.36	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
242	10.26	A	H	3	6.9	0.36	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
243	10.26	A	H	4	7.9	0.62	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
244	10.26	A	H	5	24.3	1.73	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
245	10.26	B	H	W	57.8	.	.	9	.	9	.	.	0.060	9	.	.	0.517	9	.	.	0.009	9	.	9

OBS	SNCONC	SECODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
228	.	9	.	9	.	.	0.426	0.004	0.027	0.024	0.009	.	0.007	0.007	0.015	0.011	0.011	0.009	.
229	.	9	.	9	.	.	0.678	0.006	0.033	.	0.011	.	.	0.006	.	0.014	0.014	0.011	.
230	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
231	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
232	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
233	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
234	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
235	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
236	.	9	.	9	.	.	1.101	0.005	0.032	.	0.010	.	0.008	0.008	0.018	0.013	0.013	0.010	.
237	.	9	.	9	.	.	0.738	0.005	0.029	.	0.010	.	.	.	.	0.012	0.012	0.010	.
238	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
239	0.021	9	.	9	.	.	1.119	0.005	0.031	.	0.010	.	0.008	.	0.018	.	0.013	0.010	.
240	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
241	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
242	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
243	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
244	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
245	.	9	.	.	0.009	.	1.335	0.005	0.028	.	0.009	.	0.007	.	0.016	0.012	0.012	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
246	10.26	C	F	G	110.1	3.28	14.63	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
247	10.26	D	F	G	129.1	3.52	16.66	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
248	10.26	E	M	*	63.7	.	.	9	.	.	0.189	.	0.054	9	.	.	0.002	9	.	.	0.013	9	.	9
249	10.31	A	M	*	122.2	.	.	9	.	9	.	.	0.116	9	.	.	0.287	9	.	9	.	9	.	9
250	10.31	A	M	1	33.2	0.28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
251	10.31	A	M	2	18.9	0.20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
252	10.31	A	M	3	14.0	0.19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
253	10.31	A	M	4	15.9	0.29	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
254	10.31	A	M	5	37.8	1.50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
255	10.31	B	M	G	107.7	3.28	14.63	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
256	10.31	C	M	*	187.0	.	.	9	.	9	.	.	0.103	9	.	.	0.008	.	0.01	9	.	9	.	9
257	10.31	D	M	*	115.5	.	.	9	.	9	.	.	0.154	.	0.010	.	0.225	9	.	9	.	9	.	.
258	10.31	E	F	G	105.6	2.91	19.03	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
259	11.05	A	M	*	30.8	.	.	9	.	9	.	9	.	9	.	.	0.340	9	.	9	.	9	.	9
260	11.05	A	M	1	12.5	0.01	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
261	11.05	A	M	2	9.3	0.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
262	11.05	A	M	3	5.5	0.05	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
263	11.05	A	F	*	3.2	0.10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
246	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
247	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
248	.	9	.	9	.	.	2.300	0.005	.	.	0.010	.	0.008	.	0.018	0.013	0.013	0.010	.
249	.	9	.	9	.	.	1.125	0.005	0.032	.	0.011	.	0.008	0.008	0.019	0.013	0.013	0.011	.
250	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
251	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
252	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
253	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
254	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
255	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
256	.	9	.	9	.	.	1.004	0.005	0.030	.	0.010	.	.	0.007	0.017	0.012	0.012	0.010	.
257	0.024	9	.	9	.	.	0.995	0.005	0.029	.	.	.	0.007	0.007	0.017	.	0.012	0.010	.
258	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
259	.	9	.	9	.	.	0.181	0.008	0.050	0.046	0.017	.	0.013	0.013	0.029	0.021	0.021	0.017	.
260	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
261	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
262	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
263	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
264	11.05	A	H	S	10.0	0.47	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
265	11.05	B	H	*	45.4	.	.	9	.	9	.	9	.	9	.	.	0.367	9	.	9	.	9	.	9
266	11.05	C	H	G	48.1	1.67	9.98	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
267	11.05	D	H	G	49.0	1.94	11.19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
268	11.05	E	H	*	51.7	.	.	9	.	9	.	9	.	9	.	.	0.195	9	.	9	.	9	.	9
269	11.10	A	H	*	.	.	.	9	.	9	.	9	.	9	.	.	0.299	9	.	9	.	9	.	9
270	11.10	A	H	1	.	0.17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
271	11.10	A	H	2	.	0.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
272	11.10	A	H	3	.	0.17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
273	11.10	A	H	4	.	0.16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
274	11.10	A	H	5	.	0.33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
275	11.10	B	H	G	24.2	2.70	10.94	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
276	11.10	C	H	*	2.7	.	.	9	.	9	.	9	.	9	.	.	0.291	9	.	9	.	9	.	9
277	11.10	D	H	*	1.9	.	.	9	.	9	.	9	.	9	.	.	0.284	9	.	9	.	9	.	9
278	11.10	E	H	G	26.3	1.76	6.73	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
279	11.15	A	H	*	55.9	.	.	9	.	9	.	.	0.045	9	.	.	0.045	9	.	9	.	.	0.021	9
280	11.15	A	H	1	24.3	0.31	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
281	11.15	A	H	2	6.1	0.08	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

OBS	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
264	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
265	.	9	.	9	.	.	0.247	0.008	0.046	0.042	0.015	.	0.011	0.011	0.027	0.019	0.019	0.015	.
266	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
267	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
268	.	9	.	9	.	.	0.237	0.008	0.046	0.042	0.015	.	0.011	0.011	0.027	0.019	0.019	0.015	.
269	.	9	.	9	.	.	0.184	0.008	0.048	0.044	0.016	.	0.012	0.012	0.028	0.020	0.020	0.016	.
270	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
271	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
272	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
273	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
274	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
275	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
276	.	9	.	9	.	.	0.520	0.010	0.059	0.054	0.020	.	0.015	0.015	0.035	0.025	0.025	0.020	.
277	.	9	.	9	.	.	0.218	0.007	0.044	0.041	0.015	.	0.011	0.011	0.026	0.018	0.018	0.015	.
278	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
279	.	9	.	.	0.013	.	0.619	0.005	0.032	.	0.010	.	0.008	0.008	.	0.013	0.013	.	.
280	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
281	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE	SNCONC
282	11.15	A	M	3	4.4	0.17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
283	11.15	A	M	4	2.3	0.14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
284	11.15	A	M	5	19.2	1.00	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
285	11.15	B	M	*	49.0	.	.	9	.	9	.	9	.	9	.	.	0.225	9	.	9	.	9	.	9	.
286	11.15	C	M	G	83.8	1.37	8.96	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
287	11.15	D	M	G	141.9	4.07	13.65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
288	11.15	E	M	*	50.0	.	.	9	.	9	.	9	.	9	.	.	0.348	9	.	9	.	9	.	9	.
289	11.20	A	M	*	43.8	.	.	9	.	9	.	9	.	9	.	9	.	9	.	9	.	9	.	9	.
290	11.20	A	M	1	6.9	0.20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
291	11.20	A	M	2	8.6	0.14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
292	11.20	A	M	3	3.2	0.15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
293	11.20	A	M	4	2.3	0.21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
294	11.20	A	M	5	13.0	0.85	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
295	11.20	B	M	G	44.7	1.35	12.70	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
296	11.20	C	M	*	49.5	.	.	9	.	9	.	.	0.041	9	.	.	0.131	9	.	9	.	9	.	.	0.019
297	11.20	D	M	*	37.3	.	.	9	.	9	.	.	0.053	9	.	.	0.207	9	.	9	.	9	.	9	.
298	11.20	E	M	G	41.9	1.54	12.33	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
299	11.25	A	M	*	24.3	.	.	9	.	9	.	.	0.029	.	0.009	.	0.344	9	.	9	.	9	.	.	0.012

OBS	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
282	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
283	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
284	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
285	9	.	.	0.011	.	0.628	0.004	0.026	0.024	0.009	.	0.007	0.007	0.015	0.011	0.011	.	.
286	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
287	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
288	9	.	9	.	.	0.578	0.005	0.029	0.026	0.039	.	0.007	0.007	0.017	0.012	0.012	0.009	.
289	9	.	9	.	.	0.205	0.003	0.050	0.046	0.017	0.017	0.012	0.012	0.029	0.021	0.021	0.017	.
290	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
291	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
292	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
293	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
294	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
295	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
296	9	.	.	0.019	.	0.303	0.007	0.045	.	0.015	.	0.011	0.011	0.026	.	0.019	.	.
297	9	.	.	0.028	.	0.221	0.007	0.042	.	0.014	.	0.010	0.010	0.024	0.017	0.017	.	.
298	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
299	9	.	.	0.014	.	0.255	0.005	0.029	.	.	.	0.007	0.007	0.017	.	0.012	.	.

(continued)

TABLE E-5 (continued)

OBS	DATE	LOCATION	PLANTID	FILTER	TSP	NO3CONC	SO4CONC	VCODE	VCONC	CRCODE	CRCONC	MNCODE	MNCONC	NICODE	NICONC	CUCODE	CUCONC	ASCODE	ASCONC	SECODE	SECONC	CDCODE	CDCONC	SNCODE
300	11.25	A	M	1	9.3	0.24	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
301	11.25	A	M	2	6.2	0.10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
302	11.25	A	M	3	2.4	0.44	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
303	11.25	A	M	4	5.5	0.25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
304	11.25	A	M	5	9.7	0.64	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
305	11.25	B	M	*	28.1	.	.	9	.	9	.	9	.	9	.	.	0.467	9	.	9	.	9	.	9
306	11.25	C	M	6	40.8	1.05	10.34	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
307	11.25	D	M	6	71.2	1.88	13.96	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
308	11.25	E	M	*	35.5	.	.	9	.	9	.	.	0.035	9	.	.	0.550	9	.	9	.	9	.	9
309	11.30	A	M	*	47.6	.	.	.	0.008	9	.	.	0.103	9	.	.	0.340	.	0.023	9	.	9	.	.
310	11.30	A	M	1	18.8	0.27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
311	11.30	A	M	2	16.1	0.23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
312	11.30	A	M	3	15.0	0.23	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
313	11.30	A	M	4	12.1	0.28	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
314	11.30	A	M	5	21.5	0.79	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
315	11.30	C	M	*	46.1	.	.	.	0.009	.	0.035	.	0.075	.	0.009	.	0.604	9	.	9	.	9	.	9
316	11.30	D	M	*	62.9	.	.	.	0.008	9	.	.	0.097	9	.	.	0.893	.	0.021	9	.	9	.	9

OBS	SNCONC	SBCODE	SBCONC	HGCODE	HGCONC	PBCODE	PBCONC	VDLIMIT	CRDLIMIT	MNDLIMIT	NIDLIMIT	CUDLIMIT	ASDLIMIT	SEDLIMIT	CDDLIMIT	SNDLIMIT	SBDLIMIT	HGDLIMIT	PBDLIMIT
300	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
301	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
302	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
303	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
304	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
305	.	9	.	.	0.008	.	0.256	0.004	0.025	0.023	0.008	.	0.006	0.006	0.015	0.011	0.011	.	.
306	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
307	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
308	.	9	.	9	.	.	0.693	0.005	0.028	.	0.009	.	0.007	0.007	0.016	0.012	0.012	0.009	.
309	0.015	9	.	9	.	.	0.704	.	0.031	.	0.010	.	.	0.008	0.018	.	0.013	0.010	.
310	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
311	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
312	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
313	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
314	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
315	.	9	.	9	.	.	0.741	.	.	.	.	.	0.007	0.007	0.015	0.011	0.011	0.009	.
316	.	9	.	.	0.013	.	1.088	.	0.032	.	0.010	.	.	0.008	0.018	0.013	0.013	.	.

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TABLE E-6. NON-VIABLE SEWAGE DATA SET[a]

Date	Time	SO_4[b]	NO_3[b]	V[c]	Ni[c]	Cu[c]	As[c]	Se[c]	Cd[c]	Sn[c]	Sb[c]	Hg[c]	Pb[c]
0703	1830	35.2	12.4										
0708	1516	41.8	10.3										
0713	1810	41.8	8.3										
0723	1000	50.6	8.4										
0728	2115	42.0	4.1										
0802	1100	38.5	12.2	<12	212	60	260	<2	107	55	<1	4	420
0807	1615	33.0	9.8										
0812	1730	15.4	2.9										
0817	1500	36.2	8.4										
0822	1645	37.8	12.8										
0827	1815	65.4	12.4	<12	348	841	340	<2	256	87	<1	<4	530
0901	1915	13.2	1.1	<12	225	706	70	<2	231	69	<1	<4	674
0906	1700	35.0	15.8	<12	159	81	160	<2	111	56	<1	<4	386
0911	1700	36.2	6.7	<12	261	642	260	<2	232	66	<1	<4	257
0916	2050	12.3	8.3	<12	113	49	150	<2	61	25	2	<4	273
0921	1100	28.8	9.3	<12	128	80	190	<2	63	42	<1	<4	280
0926	2130	4.3	1.1										
1001	1800	38.6	10.4	<12	228	117	150	<2	140	74	1	<4	287
1006	2030	2.9	1.2	<12	232	373	280	<2	163	76	<1	<4	308
1011	1800	5.7	4.1	<12	164	123	150	<2	93	54	<1	<4	183
1016	2200	11.4	4.3	<12	249	251	170	<2	123	68	4	<4	229
1021	2100	0.5	2.4	<12	210	203	140	<2	112	69	3	<4	203
1026	1130	6.4	10.6	<12	226	294	180	<2	142	72	<1	<4	261
1031	1300	35.7	16.0	<12	218	90	110	<2	71	59	1	<4	119
1105	1830	12.9	8.1	<12	225	12	130	<2	86	66	3	<4	187
1110	1030	27.2	1.8										
1115	2150			<12	276	7	150	<2	118	63	1	<4	176
1120	2000			<12	182	4	151	<2	88	51	7	<4	155
1125	1130			<12	174	175	140	<2	141	57	3	<4	215
1130	1930	8.6	2.2	<12	248	29	74	<2	117	39	2	<4	119

[a] Samples below detection limit reported as < detection limit.

[b] Concentration in mg/liter.

[c] Concentration in μg/liter.

APPENDIX F

AIRBORNE TOTAL AND FECAL COLIFORM COLLECTED WITH AN LVAS

Date 1977	Site	Position	Time Started	Voltage KV	Total Coliform			Fecal Coliform		
					Air Volume, m^3	Fluid Volume, ml	Conc. cfu/m^3	Air Volume	Fluid Volume	Conc. cfu/m^3
0824	2	upwind	1350	10	17	90	0	15	90	0
	4	downwind	1120	10	15	110	0.6	15	110	0.07
	11	downwind	1750	10	15	60	0	15	60	0
0831	3	upwind	1050	10	15	170	0	15	140	0
	1	downwind	1310	10	15	130	0.13	15	120	0
	6	downwind	1520	10	15	110	0.33	15	90	0
0907	3	upwind	1055	10	15	90	6.8	15	70	0.2
	1	downwind	1350	10	15	85	1.2	15	85	0.13
	6	downwind	1550	10	15	100	0.73	15	110	0
	14	downwind	1735	10	a			11	90	0
0914	1	upwind	1110	10	15	120	1.0	b		b
	3	downwind	1330	10	15	100	16.0	15	95	0.67
	10	downwind	1530	10	15	110	1.27	15	100	0.2
0921	1	upwind	1217	15	15	125	0.53	15	100	0.07
	3	downwind	1440	15	15	110	9.67	15	100	4.13
	18	downwind	1700	15	15	100	0.87	15	85	0
1005	4	upwind	1100	15	15	110	0.27	15	100	0
	7	downwind	1300	15	15	105	0.13	15	100	0
	15	downwind	1745	15	15	80	0.53	15	80	0

(continued)

AIRBORNE TOTAL AND FECAL COLIFORM COLLECTED WITH AN LVAS (continued)

1102	3	upwind	1100	15	15	95	1.0	15	100	0
	1	downwind	1700	10	15	105	12.93	15	95	3.07
	6	downwind	1300	15	15	95	0.27	15	95	0
	14	downwind	1500	15	15	120	5.13	15	115	0.87
1116	4	upwind	1015	15	15	120	1.2	15	140	0.73
	2	downwind	1350	15	15	85	15.8	15	100	7.33
	7	downwind	1200	15	15	170	0.2	15	120	0.07
	15	downwind	1530	15	15	100	4.33	15	100	0
1130	2	upwind	1045	15	15	90	0.47	15	100	0
	4	downwind	1240	15	15	150	13.93	15	120	0

(a) Sample not collected.

(b) Sample contaminated.

APPENDIX G

TWO-WEEK PERIOD TOTAL VIABLE PARTICLE EXPOSURE INDEX CALCULATION

The difference between the 2-week index and the study-period index involves how the measurement data were summarized for the SYMAP program. For the study-period case, all data were averaged by location and wind direction. These averages were then fed directly into the mapping program. In the case of the 2-week periods, however, the environmental data set consists of only five runs. This means that a maximum of five of the eight wind directions could have any data at all. In most cases, the number of wind directions with any data was four or less.

In order to develop an accurate exposure index using SYMAP, a concentration at all 20 monitoring sites was necessary. A model was developed to predict a concentration at every monitoring site for each 2-week period. The input to the model was the four average position variables for average position variables. The concentration at each location for each 2-week period is calculated by:

$$\mathrm{BICONC}_{x,y} = (\mathrm{BICONC}_{x,y'}) \left(\frac{\mathrm{CONC}_{y}}{\mathrm{CONC}_{y'}}\right)$$

y' = position associated with location y

x = 2-week period (biweek)

y = location

$\mathrm{BICONC}_{x,y}$ = biweekly (period x) concentration at site y

$\mathrm{BICONC}_{x,y'}$ = biweekly (period x) position concentration associated with site y

CONC_{y} = study-period concentration at y

$\mathrm{CONC}_{y'}$ = study-period position concentration associated with site y